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STUDY OF COST/BENEFIT TRADEOFFS  
FOR REDUCING THE ENERGY CONSUMPTION  
OF THE COMMERCIAL  
AIR TRANSPORTATION SYSTEM

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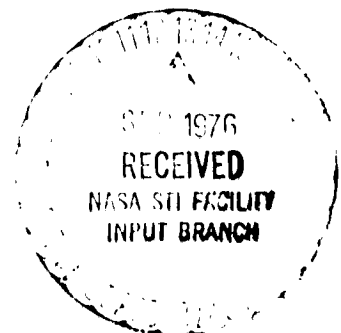
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## SYMBOLS AND ABBREVIATIONS

A/C	Aircraft	M	Mach Number
APL	Airplane	MIL	Million
APU	Auxiliary Power Unit	NNT	New Near-Term Aircraft
ASM	Available-Seat-Mile (Nautical)	O-D	Origin-Destination
ATA	Air Transport Association of America	PSGR	Passenger
ATC	Air Traffic Control	REG COF	Regression Coefficient
BTU	British Thermal Unit	ROI	Return on Investment
BIL	Billion	RPM	Revenue-Passenger-Mile (Nautical)
CAB	Civil Aeronautics Board	SAL & EXP	Salary and Expense
DOC	Direct Operating Cost	SAM	Sound Absorption Material
EPNdB	Effective Perceived Noise (level) in decibels	TOGW	Takeoff Gross Weight
F	First Class	UAL	United Airlines
FAA	Federal Aviation Administration	UTRC	United Technologies Research Center
FAN	Future Aircraft Needs (Model)	WTD	Weighted
FAR	Federal Aviation Regulation	Y	Coach (Tourist) Class
F/Y	First Class/Coach Class		
G&A	General & Administrative (Overhead)		
GND	Ground		
GNP	Gross National Product		
IAS	Indicated Air Speed		
INTER	Y-Intercept		
IOC	Indirect Operating Cost		



## ABSTRACT

Economic studies were conducted for three general fuel conserving options: (1) improving fuel consumption characteristics of existing aircraft via retrofit modifications; (2) introducing fuel efficient derivations of existing production aircraft and/or introducing fuel efficient, current state-of-the-art new aircraft; and (3) introducing an advanced state-of-the-art turboprop airplane. The economic studies were designed to produce an optimum fleet mix for United's system for the years 1980, 1985 and 1990.

The fleet selected for the study years accommodated a normal growth market by introducing somewhat larger aircraft while solving for maximum departure frequencies and a minimum load factor corresponding to a fifteen percent investment hurdle rate. Fuel burn per available-seat-mile flown dropped 22% from 1980 to 1990 due to the use of more fuel efficient aircraft designs, larger average aircraft size, and increased seating density. Adding winglets or wingtip extensions and incorporating certain drag reduction modifications to existing aircraft would yield a small but measurable increase in fuel efficiency and may be economically feasible. Re-engining JT3D powered aircraft would significantly reduce fuel consumption but would not be economically viable.

An inflight survey was taken to determine air traveler attitudes towards a new generation of advanced turboprops. An advanced turboprop offers substantial fuel and cost benefits and would be acceptable to the traveling public even with trip times measurably longer than turbofans provided it would not operate in direct competition with turbofans; or it could directly compete if it offered a fare advantage.

## SECTION 1

### INTRODUCTION AND SUMMARY

#### INTRODUCTION

The energy crisis that developed late in 1973 had a profound impact upon air transportation as an energy intense sector of the economy. The primary initial response of the airlines was the grounding of fuel inefficient aircraft. Following this was the search for means to increase the fuel efficiency of those operations that were continued. The objective of increased fuel efficiency transcended airlines, as governmental agencies, manufacturers and other elements of the air transport industry also sought improvement opportunities. Under NASA sponsorship, this study was undertaken to determine the most promising approaches for the future and assess their costs and benefits.

#### Study Participants and Scope

This study was conducted jointly by the Douglas Aircraft Company, the Lockheed California Company, United Technologies Research Center (UTRC), and United Airlines (United or UAL). The airframe manufacturers' tasks included development of cost and benefit assessments for these fuel conserving alternatives:

- Improved airline operational procedures.
- Modifications that could be retrofit to existing fleet aircraft.
- Modifications to existing aircraft designs that are practical for application only on the production line and not for retrofit.
- Derivative configurations of existing aircraft designs.
- New fuel-conservative aircraft for near-term (1980) introduction. Three basic turbofan designs were evaluated for these capacity/range criteria: (1) 200 passengers/1500 n mi; (2) 200 passengers/3000 n mi; and (3) 400 passengers/3000 n mi. Each of these basic designs were then optimized for three different sub-criteria: minimum DOC with \$79/m<sup>3</sup> (30¢/gal) fuel, minimum DOC with \$158/m<sup>3</sup> (60¢/gal) fuel, and minimum fuel consumption.

United Technologies Research Center's tasks were to provide overall coordination for the study, develop demand forecasts and fleet projections, and estimate the effects of the fuel conserving options for the total domestic air transport system.

United Airlines' role in part was to provide real world guidance to the conduct of the study and assess study results from an airline standpoint. Other major tasks included (1) development of historical operating cost and fuel consumption data for the existing UAL aircraft, (2) development of demand forecasts and fleet projections, (3) assessment of the economic viability of the various fuel conserving options and (4) identification of the research and technical support necessary to achieve improved fuel efficiency. The historical cost and fuel burn data was used as the baseline for assessing the effectiveness of operational and retrofit modification options. The fleet and demand forecasts developed by UAL apply only to UAL's system whereas the UTRC forecasts apply to all domestic carriers.

Midway through the study, the program was expanded to include evaluation of new turboprop aircraft that would incorporate an advanced prop-fan. The presumption for this evaluation is cabin comfort and cruise speed equivalent or near-equivalent to conventional narrow-body turbofans. UAL's major task in this phase was completion of a passenger survey designed to determine traveler attitudes toward turboprops and to what extent comfort, safety, environmental and other factors might influence these attitudes.

#### Study Ground Rules

In order to establish a basis for consistency in data development and analysis, the four contractors jointly, at the outset of the study, agreed to a set of ground rules the more salient of which are listed below.

##### Aircraft/Flight Operational Ground Rules

- Trip distance unit of measure: nautical miles
- Fuel heating factor: 43,260 kilo-joules/kg (18,600 BTU/lb)
- Fuel density: 815 kgs/m<sup>3</sup> (6.8 lbs/gal)
- Passenger weight including bags: 91 kgs (200 lbs)
- Noise goal for new aircraft: FAR 36 - 10 EPNdB
- Sea level/std day field length requirements for new aircraft:
  - 2130 m (7000 ft) for 200 psgr/1500 n mi vehicle
  - 2440 m (8000 ft) for 200 psgr/3000 n mi vehicle
  - 2740 m (9000 ft) for 400 psgr/3000 n mi vehicle
- Seating arrangement objectives:
  - 10%/90% F/Y mix
  - 0.965 m (38 in)/0.864 m (34 in) F/Y seat pitch
  - No lounges (excluding 747 upper deck)
  - Lower lobe galleys in 747/DC-10/L-1011

##### Cost/ROI Oriented Ground Rules

- Cost and fuel burn data base year: 1973
- Standard cost quantity for new airplane pricing: 250 airplanes

- Spare parts cost: 15% of a/c flyaway cost
- Passenger load factor: 58%
- Cargo revenue: 10% of passenger revenue
- Return on Investment: 15% discounted cash flow
- Demand growth:
  - 4.7% per year 1973 to 1980
  - 4.3% per year 1980 to 1985
  - 3.7% per year 1985 to 1990

United deviated from these ground rules in certain instances. For example, the 58% load factor was not used. Instead, load factor was a dependent variable in the economic evaluation. Also, the above demand growth projections had been superseded by more current projections available at the time the economic analysis was conducted. These new demand growth projections average 5.1% per year.

The use of nautical miles as the trip distance unit of measure is stressed. Whenever quantitatively used in this report, the abbreviations RPM and ASM denote revenue-passenger-nautical-mile and available-seat-nautical-mile, respectively.

#### UTRC Consultation

During the course of the study, United Airlines provided cost, yield and return on investment data as requested by United Technologies Research Center. The material furnished fell in three general areas:

- Yield, cost and operational data for existing aircraft.
- Technical data as necessary to describe the fuel saving design options. Much of this data was furnished to United Airlines by Douglas and Lockheed.
- Economic screen material and associated data for the fuel saving options.

United's average yield from online 1973 actual Origin and Destination data was used to develop the yield material. This data was modified to reflect the impact of the phase 9 CAB Domestic Passenger Fare Investigation, which shifted short haul fares upward and long haul fares downward. Using United's fare structure as a base, the pivotal length of haul point for the shift was between 800 and 850 nautical miles. The operational data are described in section 2 of this study.

The flow of technical data estimates to UTRC for the fuel conserving options consisted of: acquisition or modification cost, introductory year, block fuel, block speed, direct operating costs, seating capacity and maximum useful range.

Return on investment data furnished to UTRC were reflected in economic screens provided by United Airlines. United Technologies requested sufficient screen data for selected distances for each aircraft design candidate to enable them to rank the economic value of each proposal. In addition to the designs tested in United's study, an economic screen was produced for an advanced turboprop design based on a DC-9-30 airframe.

## SUMMARY

### Cost Development and Performance Analysis

United normally develops direct and indirect operating cost estimates based on its own cost data bank and methodologies in lieu of using cost estimating formulae such as the 1967 ATA DOC equations. For new production aircraft studied during this program the airplane data was insufficient to permit such a micro analysis of direct operating costs. Therefore, manufacturer estimates, developed primarily using DOC equations and handbook data, were utilized with some adjustment for airline realism. Airplane range data developed by manufacturers usually is based upon zero-wind, standard day conditions. United adjusted the range data, where appropriate, to account for 90% winter headwinds and thereby provide a maximum useful range for scheduling purposes.

### Operational Procedures

In reviewing potential changes in flight procedures to achieve fuel conservation, no significant opportunities were identified within the constraints of the existing ATC system. Fuel savings through reduced cruise speed were achieved by United during a major cost reduction effort several years prior to the Arab oil embargo. Operationally, seating density and load factor increases are the chief remaining opportunities for improved fuel efficiency. (Improvements in the ATC system, studied by Douglas, Lockheed and UTRC, but not United, may offer significant increases in fuel efficiency.)

### Airline Realism

Aircraft technology translated into performance and operating cost improvements play an important role in fleet planning decisions. Changes in the economic environment (fuel availability and price, for example) bearing on fleet purchase decisions will advance the application of improved technologies. The major variables in an airline's economic environment are: market size and growth, yield escalation and yield level, cost escalation, capital availability and investment hurdle rate. These factors collectively have been referred to in this study as "Airline Realisms".

Assuming that there are no future imposed fuel or operating constraints, nor that another 1974/1975 magnitude fuel price escalation will take place, we forecast a long range RPM market growth of about five percent per year accompanied by an average ASM growth of about four and one-half percent. This

forecast results in a continued upward shift in load factor, which is required in part by our planning expectations that cost escalation will continue to outdistance yield escalations. At the same time, we project a continuation of past trends of a proportionate trunk carrier traffic shift from shorter haul to longer haul markets. The market share composition of the airline industry is expected to change during study forecast period. However, since the direction and magnitude of such changes are unpredictable, we assumed a constant market share for United for purposes of this study.

United employs an investment hurdle rate concept for investment decisions. This hurdle rate is based on considerations for a desired debt/equity ratio and need to meet an after tax payback requirement of 10 to 11%. The investment rate must also include allowances for a sizeable capital requirement on projects with no financial advantage. All of these financial considerations establish United's current investment hurdle rate at 15%.

If an aircraft design, measured in terms of the realisms of traffic, cost and yield forecasts cannot achieve the cost of capital investment hurdle rates of enough airlines to generate sufficient orders for the start of a production program, the fuel saving aspects of that design will never be realized. Due to depressed profitability in the airline industry, the growing possibility exists that no capital will be available because the financial situation of many carriers makes investment risks too high for lenders. This is particularly true when superior opportunities exist in other industries.

Airline economics are applied to the study fleet choices through the use of economic screens and segment forecasts. Fleet planning economic screens are tools used at United to indicate how many passengers are required over a given segment length and for a given aircraft or fleet mix to meet a predetermined investment hurdle rate. In another model (called the Future Aircraft Needs model) the projected market in terms of segment passengers is matched with the economic screen for fleet types under evaluation to determine the number and types of aircraft needed to carry passengers over each segment on the route system. Calculations based on assumed daily aircraft utilization as well as operational and market requirements make it possible to summarize the number and type of aircraft needed to cover both the segment and the total system.

#### Economic Findings

Four fleet combinations were tested; three for the 1980 market projection and one for the 1985 market projection. It is unlikely an airline would replace a complete fleet at one time; therefore, only the most likely replacement candidates in United's current fleet were allowed to be removed from service. In the 1980 fleet scenario, two derivative aircraft, the 727-300 and a two-engine DC-10, were tested in alternative fleet compositions. However, they were only selected in a very limited quantity suggesting that their capacities (156 and 199 seats, respectively) are the lower and upper limits of a short to medium haul replacement aircraft for the early and mid 1980's.

Fuel saving aerodynamic modifications (drag reduction and winglets or wing tip extensions) proved to be only marginally successful. On balance, such modifications would probably provide an economic payoff. Re-engining modifications did not appear economically advantageous. None of the new near-term aircraft designs, which were specifically aimed at fuel saving, were selected by the model in sufficient quantities to be viable in a 1985 United fleet. (Derived for 1980 introduction these designs were not input in the model until 1985.) Though equally limited in the 1990 fleet, the designs show some economic promise for the 1990's and were therefore left in solution. From 1978 through 1990, the total capital required for United to purchase the selected number of proposed aircraft designs and to perform aerodynamic modifications (in 1973 dollars net of aircraft sales) is estimated to be about \$2.7 billion.

#### Turboprop Consumer Research Study

An inflight survey was conducted to determine passenger attitudes toward an advanced, fuel conserving turboprop airplane. Before introducing the advanced turboprop, travelers were asked some questions to enable assessment of current attitudes. The salient conclusions from the preliminary questions were:

- There exists today a strong preference for jets (87% of the respondents) compared to propeller aircraft preferences (2%).
- The traveler has a high degree of concern for price (air fares).
- The traveler has a high degree of concern for seating comfort.
- The traveler also has a high degree of concern for speed; however, the concern for speed is subordinate to the concerns for both price and seating comfort.

After the preliminary questions, the advanced turboprop was introduced citing ride quality and safety at levels comparable to jets. Thirty-seven percent (37%) of the respondents indicated they would want to fly such a vehicle, 14% would not, and 49% wouldn't care one way or the other. Then, when possible advantages for the advanced turboprop were introduced--fuel conservation, avoidance of fare increases, less airport noise--the respondents' attitudes shifted significantly. Up to 84% of the respondents would then want to fly the advanced turboprop and only 7% would not. With the possible advanced turboprop advantages in mind, the respondents also indicated that turboprop cruise speeds slower than turbofans would be permissible. A tolerance for increased flight times up to five minutes per hour was expressed. From the consumer research study, we believe that the following two conclusions are reasonable, subject to further validation:

- Though preferring a jet today, a passenger would fly an advanced turboprop having jet equivalent speed, seating

comfort and ride quality if he perceived a significant fuel savings attendant with the turboprop.

- The passenger would fly an advanced turboprop with a trip time measurably longer than jets if a direct financial advantage was associated with the turboprop; e.g., a posted, discernible jet/advanced turboprop fare differential.



## SECTION 2

### BASELINE FUEL AND COST DATA

Actual 1973 fuel consumption and operating costs are tabulated and discussed in this section for nine of United's active fleets. This data provides the baseline for assessing the benefits and penalties of energy reducing procedures, modifications and new aircraft. In addition to costs and fuel efficiency, this section includes assessment of: (1) costs that might be incurred in extending the useful life of existing aircraft; (2) the purchase cost of new aircraft still in production and purchase cost of used out-of-production vehicles; and (3) segment fare yields based on actual 1973 fares and based on CAB Domestic Passenger Fare Investigation phase 9, had that fare structure been in effect during 1973.

The fuel consumption and operating costs are tabulated versus trip distance. Five trip distances have been selected for each fleet. These distances are identified in table 2-1. It was considered desirable to have at least two distances common to all fleets; 500 n mi and 1000 n mi were selected. The longest trip distance, except for the 737, approximates United's longest revenue usage of the particular airplane type.

TABLE 2-1  
SELECTED STUDY  
TRIP DISTANCES

Trip Distance (Naut. Mi.)	Aircraft								
	737-200	727-100	727-200	DC-8-20	DC-8-51/-52	DC-8-61	DC-8-62	DC-10-10	747-100
200	✓								
300	✓	✓	✓						
500	✓	✓	✓	✓	✓	✓	✓	✓	✓
750	✓	✓	✓						
1000	✓	✓	✓	✓	✓	✓	✓	✓	✓
1500				✓	✓	✓		✓	
1750		✓	✓						
2000				✓	✓	✓	✓	✓	✓
2500				✓	✓	✓		✓	
3000							✓		✓
4000									✓
4500							✓		

## DIRECT OPERATING COSTS

Baseline direct operating cost (DOC) data has been developed utilizing United's 1973 schedule P-5.2 form 41 reporting to the CAB. The DOC cost elements used in this study are the standard ATA cost categories with one exception: a new category "aircraft registry tax" has been added. This addition has been made to isolate the registry tax from non-refundable state and local fuel taxes. These taxes are combined, for CAB reporting, in CAB account 5169 "taxes - other than payroll". The correlation of DOC elements used in this study with UAL schedule P-5.2 elements is provided in table 2-2.

Tables 2-3 and 2-4 tabulate DOC's per block-hour and per available-seat-mile, respectively, for the trip distances identified in table 2-1. The seat-mile costs are portrayed graphically in figure 2-1. These data indicate that stretched aircraft versions (727-200 and DC-8-61) have measurably lower seat-mile costs. The DC-8-62's cost level is influenced heavily by its depreciation element and is specifically discussed below under the sub-topic "Flight Equipment Depreciation".

The block-hour and seat-mile costs were computed using the table 2-5 cost factors which in turn were developed using the schedule P-5.2 data. It is important that these cost factors not be used to make airplane-to-airplane comparisons where apples and oranges comparisons will result. An example is the DC-10 and 747 maintenance costs which appear nearly equal. However, a direct comparison is not realistic as the average 747 trip segment was 70+% longer than the DC-10 and, therefore, the 747 had a much lower flight cycle to flight hour ratio. The 1973 average segment length for each aircraft is included at the bottom of table 2-5 along with average block speed and average daily utilization.

### Flight Equipment Depreciation

Depreciation is essentially an annual expense that will not vary with changes in aircraft utilization. The above warning regarding the use of block-hour cost factors is particularly applicable to this item. The use of such cost factors with arbitrary aircraft utilization data can produce highly erroneous results. The utilization data found at the bottom of table 2-5 is provided to facilitate analysis of the depreciation element.

It was mentioned above that the figure 2-1 relative cost position of the DC-8-62 was influenced heavily by depreciation expense. This is readily evident when examining the flight equipment depreciation data in table 2-4. On a cash DOC basis, the DC-8-62 curve would cluster with the DC-8-51/-52 and 727-100 airplanes. The DC-8-62 depreciation cost per seat-mile is high mainly because the purchase price per installed seat was much greater than the other aircraft. This is a compound situation. The price was high (twice that of the DC-8-50's) as it was the last DC-8 model purchased by United, has a different wing and engine and has extended range capability. The installed seat

TABLE 2-2  
DIRECT OPERATING COST ELEMENTS -  
CORRELATION WITH CAB COST ACCOUNTS

DOC Element	CAB Form 41, Schedule P-5.2
Flight Crew	5123 Pilots and copilots 5124 Other flight personnel 5128.1 Trainees and instructors 5136 Personnel expenses 5153 Other supplies 5157 Employee benefits and pensions 5158 Injuries, loss and damage 5168 Taxes Payroll 5171 Other expenses
Fuel & Oil	5145.1 Aircraft fuels 5145.2 Aircraft oils 5169 Taxes - other than payroll (excluding aircraft registry taxes)
Hull Insurance	5155.1 Insurance purchased - general 5155.2 Provisions for self-insurance - general
Maintenance Labor - Airframe	5225.1 Labor - airframes 5225.3 Labor - other flight equipment 5243.1 Airframe repairs - outside
Maintenance Labor - Engine	5225.2 Labor - aircraft engines 5243.2 Aircraft engine repairs - outside
Maintenance Material - Airframe	5246.1 Maintenance materials - airframes 5246.3 Maintenance materials - other flight equip.
Maintenance Material - Engine	5246.2 Maintenance materials - aircraft engines
Maintenance Burden	5279.6 Ap. mt. burden - flt. equip.
Flight Equipment Depreciation	7075.6 Total depr. - flight equip. 5147 Rentals
Aircraft Registry Tax	5169 Taxes - other than payroll (excluding non-refundable fuel taxes)

TABLE 2-3  
DIRECT OPERATING COSTS  
\$/Block-hour

Airplane 737-200		Trip Distance - Nautical Miles				
		200	300	500	750	1000
Maintenance Labor	- Airframe	34.35	36.82	39.61	41.37	42.34
	- Engine	9.69	10.39	11.17	11.67	11.94
Maintenance Material	- Airframe	15.37	16.48	17.73	18.52	18.96
	- Engine	16.00	17.16	18.46	19.30	19.73
Maintenance Burden		69.13	74.10	79.72	83.27	85.22
Fuel & Oil		110.51	113.53	116.88	120.70	123.29
Flight Crew				231.29		
Hull Insurance				3.51		
Aircraft Registry Tax				1.55		
Total Cash Costs		491.40	504.83	519.92	531.18	537.83
Flight Equipment Depreciation				102.44		
Total Direct Operating Costs		593.84	607.27	622.36	633.62	640.27

Airplane 727-100		Trip Distance - Nautical Miles				
		300	500	750	1000	1750
Maintenance Labor	- Airframe	33.44	36.45	38.33	39.45	41.02
	- Engine	13.76	15.00	15.78	16.24	16.89
Maintenance Material	- Airframe	18.01	19.63	20.65	21.25	22.10
	- Engine	18.90	20.59	21.66	22.30	23.18
Maintenance Burden		73.78	80.41	84.57	87.04	90.51
Fuel & Oil		160.15	154.24	154.12	152.83	155.75
Flight Crew				220.27		
Hull Insurance				3.05		
Aircraft Registry Tax				1.95		
Total Cash Costs		543.31	551.59	560.38	564.38	574.72
Flight Equipment Depreciation				133.15		
Total Direct Operating Costs		676.46	684.74	693.53	697.53	707.87

Airplane 727-200		Trip Distance - Nautical Miles				
		300	500	750	1000	1750
Maintenance Labor	- Airframe	32.67	35.70	37.68	38.77	40.37
	- Engine	13.60	14.87	15.69	16.14	16.81
Maintenance Material	- Airframe	17.74	19.39	20.47	21.06	21.93
	- Engine	19.45	21.26	22.44	23.09	24.04
Maintenance Burden		73.12	79.93	84.35	86.78	90.39
Fuel & Oil		178.04	168.75	166.07	166.63	171.97
Flight Crew				219.85		
Hull Insurance				4.45		
Aircraft Registry Tax				2.19		
Total Cash Costs		561.11	556.39	573.19	578.96	592.00
Flight Equipment Depreciation				165.86		
Total Direct Operating Costs		726.97	732.25	739.05	744.82	757.86

TABLE 2-3 (Cont.)  
DIRECT OPERATING COSTS  
\$/Block-hour

Airplane DC-8-20		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	35.07	38.20	39.47	40.15	40.59
	- Engine	18.88	20.57	21.25	21.62	21.85
Maintenance Material	- Airframe	20.60	22.44	23.18	23.58	23.84
	- Engine	29.09	31.69	32.74	33.31	33.67
Maintenance Burden		85.15	92.76	95.83	97.50	98.56
Fuel & Oil		265.85	258.97	260.79	265.00	269.32
Flight Crew		←	←	236.85	←	←
Hull Insurance		←	←	1.33	←	←
Aircraft Registry Tax		←	←	3.11	←	←
Total Cash Costs		695.93	705.92	714.55	722.45	729.12
Flight Equipment Depreciation		←	←	149.37	←	←
Total Direct Operating Costs		845.30	855.29	863.92	871.82	878.49

Airplane DC-8-51/-52		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	35.63	38.70	39.94	40.61	41.03
	- Engine	18.36	19.94	20.57	20.92	21.14
Maintenance Material	- Airframe	20.46	22.22	22.93	23.31	23.56
	- Engine	21.12	22.94	23.67	24.07	24.32
Maintenance Burden		84.66	91.96	94.89	96.48	97.49
Fuel & Oil		222.73	216.38	217.28	220.19	223.93
Flight Crew		←	←	246.09	←	←
Hull Insurance		←	←	3.13	←	←
Aircraft Registry Tax		←	←	3.34	←	←
Total Cash Costs		657.52	666.70	673.84	680.14	686.03
Flight Equipment Depreciation		←	←	218.90	←	←
Total Direct Operating Costs		876.42	885.60	892.74	899.04	904.93

Airplane DC-8-61		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	35.06	38.35	39.67	40.38	40.83
	- Engine	18.06	19.75	20.43	20.80	21.04
Maintenance Material	- Airframe	21.41	23.42	24.22	24.66	24.94
	- Engine	20.57	22.50	23.27	23.69	23.96
Maintenance Burden		83.21	91.03	94.15	95.85	96.93
Fuel & Oil		263.05	245.83	243.82	245.54	248.17
Flight Crew		←	←	252.40	←	←
Hull Insurance		←	←	5.69	←	←
Aircraft Registry Tax		←	←	3.66	←	←
Total Cash Costs		703.11	702.63	707.31	712.67	717.62
Flight Equipment Depreciation		←	←	241.65	←	←
Total Direct Operating Costs		944.76	944.28	948.96	954.32	959.27

TABLE 2-3 (Cont.)  
DIRECT OPERATING COSTS  
\$/Block-hour

Airplane <u>DC-8-62</u>		Trip Distance - Nautical Miles				
		500	1000	2000	3000	4500
Maintenance Labor	- Airframe	35.22	38.59	40.70	41.50	42.06
	- Engine	23.72	25.98	27.40	27.94	28.31
Maintenance Material	- Airframe	19.22	21.06	22.21	22.64	22.95
	- Engine	21.06	23.02	24.28	24.75	25.09
Maintenance Burden		72.65	79.59	83.94	85.58	86.74
Fuel & Oil		249.26	210.57	210.11	220.09	234.82
Flight Crew		←	←	262.67	←	←
Hull Insurance		←	←	7.08	←	←
Aircraft Registry Tax		←	←	3.92	←	←
Total Cash Costs		694.80	672.48	682.31	696.17	713.64
Flight Equipment Depreciation		←	←	340.73	←	←
Total Direct Operating Costs		<u>1035.53</u>	<u>1013.21</u>	<u>1023.04</u>	<u>1036.90</u>	<u>1054.37</u>

Airplane <u>DC-10-10</u>		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	54.04	59.88	62.37	63.74	64.62
	- Engine	27.84	30.85	32.13	32.84	33.29
Maintenance Material	- Airframe	57.21	63.39	66.02	67.48	68.40
	- Engine	67.70	75.01	78.13	79.85	80.95
Maintenance Burden		123.53	136.86	142.54	145.69	147.69
Fuel & Oil		244.35	243.18	252.57	263.85	273.82
Flight Crew		←	←	283.59	←	←
Hull Insurance		←	←	23.42	←	←
Aircraft Registry Tax		←	←	5.13	←	←
Total Cash Costs		886.81	921.31	945.90	965.59	980.91
Flight Equipment Depreciation		←	←	450.62	←	←
Total Direct Operating Costs		<u>1337.43</u>	<u>1371.93</u>	<u>1396.52</u>	<u>1416.21</u>	<u>1431.53</u>

Airplane <u>747-100</u>		Trip Distance - Nautical Miles				
		500	1000	2000	3000	4000
Maintenance Labor	- Airframe	47.65	53.46	57.44	58.98	59.81
	- Engine	34.22	38.40	41.25	42.36	42.95
Maintenance Material	- Airframe	35.80	40.16	43.15	44.31	44.93
	- Engine	81.57	91.52	98.32	100.96	102.38
Maintenance Burden		126.27	141.68	152.22	156.30	158.50
Fuel & Oil		416.29	384.98	401.94	427.53	449.84
Flight Crew		←	←	323.60	←	←
Hull Insurance		←	←	26.89	←	←
Aircraft Registry Tax		←	←	6.69	←	←
Total Cash Costs		1098.98	1107.38	1151.50	1187.62	1215.59
Flight Equipment Depreciation		←	←	506.39	←	←
Total Direct Operating Costs		<u>1605.37</u>	<u>1613.77</u>	<u>1657.89</u>	<u>1694.01</u>	<u>1721.98</u>

TABLE 2-4  
DIRECT OPERATING COSTS  
¢/Avail.-Seat-Naut. Mile

Airplane 737-200		Trip Distance - Nautical Miles				
		200	300	500	750	1000
Maintenance Labor	- Airframe	.148	.135	.127	.123	.121
	- Engine	.042	.038	.036	.035	.034
Maintenance Material	- Airframe	.067	.061	.057	.055	.054
	- Engine	.069	.063	.059	.057	.056
Maintenance Burden		.299	.272	.255	.248	.244
Fuel & Oil		.477	.417	.374	.360	.353
Flight Crew		.999	.849	.739	.689	.662
Hull Insurance		.015	.013	.011	.010	.010
Aircraft Registry Tax		.007	.006	.005	.005	.004
Total Cash Costs		2.123	1.854	1.663	1.582	1.538
Flight Equipment Depreciation		.443	.376	.326	.305	.293
Total Direct Operating Costs		2.566	2.230	1.989	1.887	1.831

Airplane 727-100/QC Psgr.		Trip Distance - Nautical Miles				
		300	500	750	1000	1750
Maintenance Labor	- Airframe	.115	.108	.104	.102	.101
	- Engine	.047	.044	.043	.042	.041
Maintenance Material	- Airframe	.062	.058	.056	.055	.054
	- Engine	.065	.061	.059	.058	.057
Maintenance Burden		.254	.238	.229	.226	.222
Fuel & Oil		.552	.456	.417	.397	.382
Flight Crew		.759	.652	.595	.572	.540
Hull Insurance		.010	.009	.008	.008	.007
Aircraft Registry Tax		.007	.006	.005	.005	.005
Total Cash Costs		1.871	1.632	1.516	1.465	1.409
Flight Equipment Depreciation		.459	.394	.360	.346	.326
Total Direct Operating Costs		2.330	2.026	1.876	1.811	1.735

Airplane 727-200		Trip Distance - Nautical Miles				
		300	500	750	1000	1750
Maintenance Labor	- Airframe	.090	.084	.082	.080	.078
	- Engine	.037	.035	.034	.033	.032
Maintenance Material	- Airframe	.049	.046	.044	.043	.042
	- Engine	.053	.050	.049	.047	.046
Maintenance Burden		.201	.187	.182	.178	.175
Fuel & Oil		.488	.396	.359	.342	.333
Flight Crew		.603	.519	.475	.451	.426
Hull Insurance		.012	.010	.010	.009	.009
Aircraft Registry Tax		.006	.005	.005	.004	.004
Total Cash Costs		1.539	1.332	1.240	1.187	1.145
Flight Equipment Depreciation		.455	.389	.359	.341	.321
Total Direct Operating Costs		1.994	1.721	1.599	1.528	1.466

TABLE 2-4 (Cont.)  
DIRECT OPERATING COSTS  
¢/Avail.-Seat-Naut. Mile

Airplane <u>DC-8-20</u>		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	.087	.082	.079	.079	.079
	- Engine	.047	.044	.043	.042	.042
Maintenance Material	- Airframe	.051	.048	.047	.046	.046
	- Engine	.072	.068	.066	.065	.065
Maintenance Burden		.210	.198	.194	.192	.191
Fuel & Oil		.657	.554	.528	.521	.521
Flight Crew		.586	.507	.479	.466	.458
Hull Insurance		.003	.003	.003	.003	.003
Aircraft Registry Tax		.008	.007	.006	.006	.006
Total Cash Costs		<u>1.721</u>	<u>1.511</u>	<u>1.445</u>	<u>1.420</u>	<u>1.411</u>
Flight Equipment Depreciation		.369	.320	.302	.294	.289
Total Direct Operating Costs		<u>2.089</u>	<u>1.831</u>	<u>1.747</u>	<u>1.714</u>	<u>1.700</u>

Airplane <u>DC-8-51/-52</u>		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	.086	.081	.079	.078	.078
	- Engine	.044	.042	.041	.040	.040
Maintenance Material	- Airframe	.050	.047	.046	.045	.045
	- Engine	.051	.048	.047	.046	.046
Maintenance Burden		.204	.193	.189	.186	.185
Fuel & Oil		.538	.454	.432	.425	.426
Flight Crew		.600	.520	.493	.479	.471
Hull Insurance		.008	.007	.006	.006	.006
Aircraft Registry Tax		.008	.007	.007	.006	.006
Total Cash Costs		<u>1.589</u>	<u>1.399</u>	<u>1.340</u>	<u>1.311</u>	<u>1.303</u>
Flight Equipment Depreciation		.529	.459	.435	.423	.416
Total Direct Operating Costs		<u>2.118</u>	<u>1.858</u>	<u>1.775</u>	<u>1.734</u>	<u>1.719</u>

Airplane <u>DC-8-61</u>		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	.063	.060	.059	.058	.058
	- Engine	.032	.030	.029	.029	.029
Maintenance Material	- Airframe	.039	.037	.036	.035	.035
	- Engine	.037	.035	.034	.034	.034
Maintenance Burden		.150	.143	.139	.138	.137
Fuel & Oil		.474	.385	.361	.353	.350
Flight Crew		.455	.395	.373	.362	.356
Hull Insurance		.010	.009	.008	.008	.008
Aircraft Registry Tax		.007	.006	.005	.005	.005
Total Cash Costs		<u>1.267</u>	<u>1.100</u>	<u>1.044</u>	<u>1.022</u>	<u>1.012</u>
Flight Equipment Depreciation		.436	.379	.357	.347	.341
Total Direct Operating Costs		<u>1.703</u>	<u>1.479</u>	<u>1.401</u>	<u>1.369</u>	<u>1.353</u>



TABLE 2-4 (Cont.)  
DIRECT OPERATING COSTS  
¢/Avail.-Seat-Naut. Mile

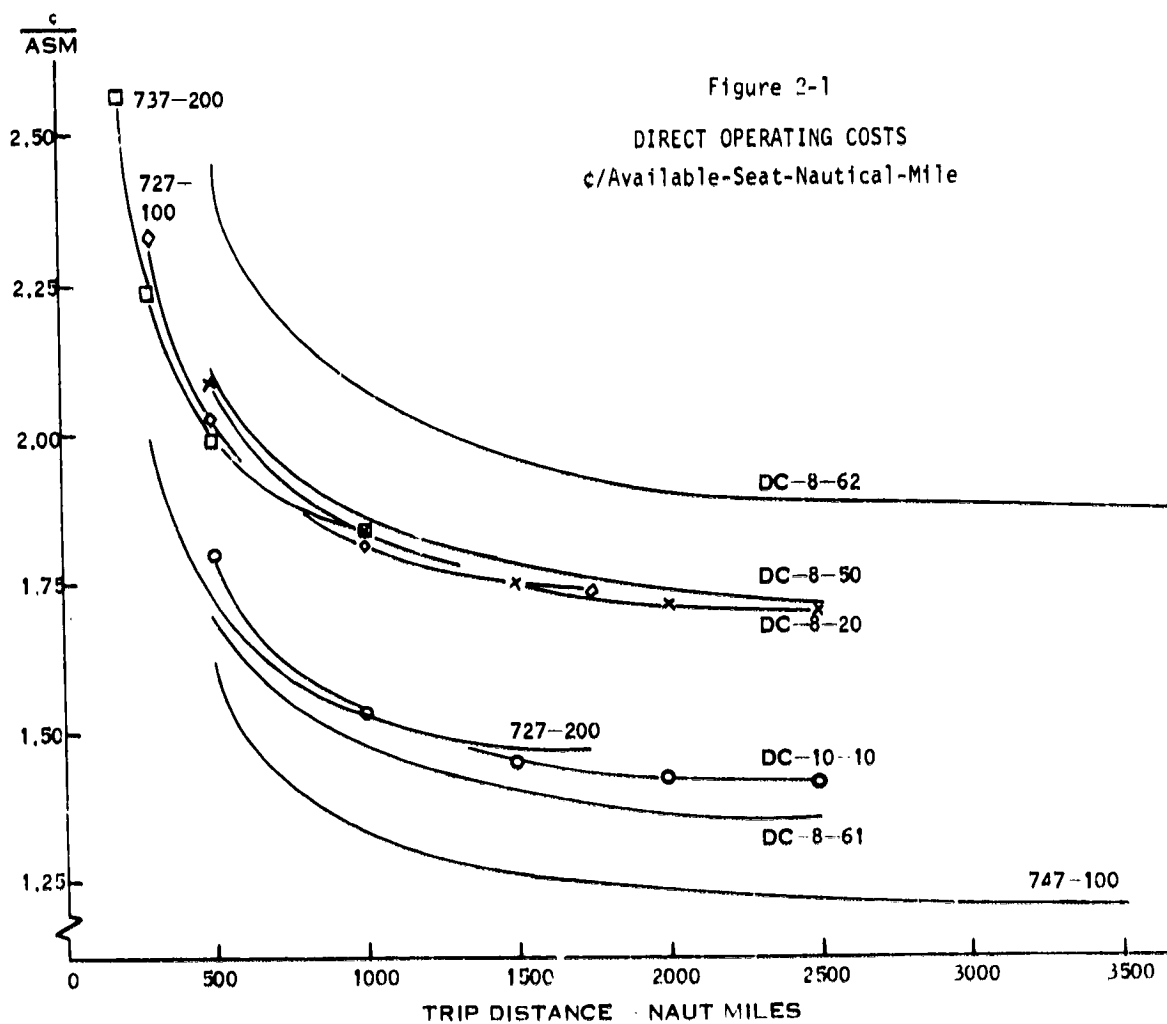
Airplane DC-8-62		Trip Distance - Nautical Miles				
		500	1000	2000	3000	4500
Maintenance Labor	- Airframe	.083	.078	.076	.075	.074
	- Engine	.056	.053	.051	.051	.050
Maintenance Material	- Airframe	.045	.043	.041	.041	.041
	- Engine	.050	.047	.045	.045	.044
Maintenance Burden		.172	.162	.156	.154	.153
Fuel & Oil		.590	.429	.391	.397	.415
Flight Crew		.621	.535	.488	.474	.464
Hull Insurance		.017	.014	.013	.013	.012
Aircraft Registry Tax		.009	.008	.007	.007	.007
Total Cash Costs		1.643	1.369	1.268	1.257	1.260
Flight Equipment Depreciation		.806	.694	.634	.614	.602
Total Direct Operating Costs		2.449	2.063	1.902	1.871	1.862

Airplane DC-10-10		Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Maintenance Labor	- Airframe	.072	.067	.065	.064	.064
	- Engine	.037	.034	.033	.033	.033
Maintenance Material	- Airframe	.076	.071	.069	.068	.067
	- Engine	.090	.084	.082	.080	.080
Maintenance Burden		.165	.153	.149	.147	.146
Fuel & Oil		.327	.272	.264	.266	.270
Flight Crew		.379	.317	.296	.286	.280
Hull Insurance		.031	.026	.024	.024	.023
Aircraft Registry Tax		.007	.006	.005	.005	.005
Total Cash Costs		1.184	1.030	.987	.973	.968
Flight Equipment Depreciation		.602	.504	.471	.454	.445
Total Direct Operating Costs		1.786	1.534	1.458	1.427	1.413

Airplane 747-100		Trip Distance - Nautical Miles				
		500	1000	2000	3000	4000
Maintenance Labor	- Airframe	.048	.044	.043	.042	.042
	- Engine	.035	.032	.031	.030	.030
Maintenance Material	- Airframe	.036	.033	.032	.032	.031
	- Engine	.083	.076	.073	.072	.072
Maintenance Burden		.128	.118	.113	.112	.111
Fuel & Oil		.422	.321	.293	.305	.315
Flight Crew		.328	.270	.241	.231	.227
Hull Insurance		.027	.022	.020	.019	.019
Aircraft Registry Tax		.007	.006	.005	.005	.005
Total Cash Costs		1.114	.922	.867	.848	.852
Flight Equipment Depreciation		.513	.422	.377	.361	.355
Total Direct Operating Costs		1.627	1.344	1.234	1.209	1.207

TABLE 2-5  
D.O.C. BASELINE COST FACTORS  
(1973 \$)

	737-200	727-100	727-200	DC-8-20	DC-8-51 /-52	DC-8-61	DC-8-62	DC-10-10	747-100
Flight Crew - S/blk-hr	231.29	220.27	219.85	236.85	248.09	252.40	262.67	283.59	323.60
Flight Insurance - S/blk-hr	3.51	3.05	4.45	1.33	3.13	5.69	7.08	23.42	26.89
Flight Equipment Depreciation - S/blk-hr	102.44	133.15	165.86	149.37	218.90	241.65	340.73	450.62	506.39
Aircraft Registry Tax - S/blk-hr	1.55	1.95	2.19	3.11	3.34	3.66	3.92	5.13	6.69
Maintenance Labor - Airframe - S/flt-hr	45.77	43.43	42.87	42.48	42.93	42.86	43.25	68.71	62.47
Maintenance Labor - Engine - S/flt-hr	12.95	17.88	17.82	22.88	22.03	22.01	29.12	35.15	44.90
Maintenance Material - Airframe - S/flt-hr	20.60	23.41	23.29	24.95	24.62	26.15	23.60	72.59	46.93
Maintenance Material - Engine - S/flt-hr	21.25	24.53	25.50	35.25	25.41	25.12	25.80	85.84	106.99
Maintenance Burden - S/flt-hr	92.18	95.82	95.92	103.16	101.87	101.63	89.20	156.67	165.61
Taxi Time - hrs/trip	.20	.23	.24	.26	.25	.27	.28	.33	.38
Ground Fuel - kgs/trip	170	281	305	608	509	537	553	505	740
- (lbs/trip)	(375)	(621)	(673)	(1342)	(1123)	(1185)	(1221)	(1115)	(1632)
Fuel (& Oil) Cost - \$/g	.04237	.04228	.04285	.04208	.04212	.04215	.04190	.04201	.04219
- (\$/lb)	(.01922)	(.01918)	(.01944)	(.01909)	(.01911)	(.01912)	(.01901)	(.01906)	(.01914)
Average Segment Length - naut. miles	257	544	447	886	1018	1044	1201	1076	1850
Average Block Speed - naut. miles/hr.	249	331	304	359	372	369	383	370	407
Average Utilization - block hrs./day	6.22	7.70	7.58	8.53	7.58	8.65	8.85	8.80	11.06
Average seats per Revenue Departure	92.6	96.7	122.8	120.5	121.5	165.4	127.7	233.5	315.6



quantity in 1973 was comparatively low (not much different than the DC-8-50's) as the aircraft was configured with 5-across coach seating. Currently with 6-across seating, the spread between DC-8-62 and DC-8-51/-52 seat quantities has increased thus reducing the DOC per seat-mile differences.

Figure 2-1 also indicates that DC-8-51/-52 seat-mile costs are higher than DC-8-20 costs. This also is a result of the depreciation element. DC-8-20 out-of-pocket DOC's are significantly higher than the DC-8-50's due to higher fuel burn (ref. table 2-3 or 2-4). Note: The depreciation element includes lease payments which are cash costs; however, lease costs are treated as non-cash costs in a majority of economic analyses.

If the depreciation cost data contained in this report are to be used for future year studies, the analyst must consider depreciation end dates. Table 2-6 identifies depreciation and lease term end dates for the nine fleets. Lease commitments account for most of the gaps between end dates. Using the DC-8-62 as an illustration, the four aircraft that are owned (44% of the entire DC-8-62 fleet) will be fully depreciated by 1980 whereas the remaining five airplanes are operated under a lease agreement whose term does not expire until 1984. A word of caution is offered regarding the use of fully depreciated aircraft in airline or airline industry return on investment analyses. In an inflationary economy, depreciation reserves will not be adequate to fund the purchase of new equipment. To better avail sufficient resources for replacement of obsolete aircraft, a replacement cost depreciation base should perhaps be used in lieu of book depreciation.

TABLE 2-6  
AIRCRAFT DEPRECIATION  
(AND LEASE) END DATES

	737	727-100	727-200	DC-8				DC-10	747
				-20	-50	-61	-62		
1974 or Prior 1975 76				100%	31% 6%				
77 78 79		19% 3%			63%				
80 81 82		20% 22% 33%	89%			17% 66%	44%		
83 84 85	50%	3%	11%			17%	56%		28%
86 87 88 89								28% 55% 17%	50% 22%

### Hull Insurance and Aircraft Registry Tax

Similar to depreciation, hull insurance and registry tax expenses are also annual in nature and will not vary with changes in aircraft utilization. Hull insurance consists of two elements: (1) purchased insurance and (2) self insurance through a reserve to protect against losses not covered by the aggregate deductible requirements in the purchased insurance policy. Purchased insurance expense (form 41 account 5155.1) is generally a function of current aircraft book value and during the past year averaged approximately 0.2% of book value. The self insurance provisions expense (account 5155.2) has been about equal to purchased insurance costs during the recent years that have been free of major hull casualty losses.

Aircraft registry tax is solely a function of the maximum allowable takeoff weight as specified in an airplane's FAA Approved Flight Manual. The taxes applicable to United's aircraft are as follows:

<u>A/C</u>	<u>Registry tax/ apl/year</u>	<u>A/C</u>	<u>Registry tax/ apl/year</u>
737-200	\$ 3,525	DC-8-20	\$ 9,685
727-100	5,675	DC-8-51/52	9,685
727-200	6,045	DC-8-61	11,400
747-100	24,875	DC-8-62	12,275
DC-10-10	14,375		

The 727-100 tax is an average value as United has three different gross weight 727-100 aircraft ranging from 152,000 to 169,000 lbs maximum takeoff weight.

### Flight Crew

Flight crew costs are commonly expressed in block-hour terms and indeed total annual crew costs are a function of the number of hours an airplane is operated during the year. However, within a given fleet, the \$ per block-hour cost rate is, among other things, a function of the ability to effectively integrate crew and airplane scheduling. This characteristic is highlighted in table 2-5 which indicates the 737 block-hour cost rate to be higher than the 727. For any specific city-pair, out-of-pocket flight crew costs may be slightly higher for the 727 because of its larger gross weight and the higher seniority of its flight crew. The higher 737 block-hour rate results because it currently requires approximately 11% more flight crew members to produce a 737 revenue block hour than to produce a 727 revenue block hour. The greater range capability of the 727 provides more flexibility in airplane routing thus enabling more productive scheduling of crew and vehicle. The range limitation of the 737 subjects it to short-haul, multiple-stop routing wherein a crew's ground time becomes a larger part of the total duty time.

## Maintenance

The reader has probably observed that table 2-3 shows maintenance cost rates increasing with trip distance. It is stressed that these rates are developed from 1973 CAB form 41 schedule P-5.2 data which provides total costs only and table 2-3 should not be considered an accurate basis for predicting maintenance costs over varying distances. The maintenance rate increase with increasing trip distance is caused by the following events:

1. Internal handling of maintenance costs on a dollars per flight-hour base (convenient as the FAA specifies time limits between maintenance checks in flight-hour terms);
2. Input of the cost per flight hour data into a computer program which computes total trip costs; and
3. Conversion of total trip costs to costs per block-hour to fulfill a contractual reporting requirement.

The block-hour cost rate computation from flight-hour costs is expressed as:

$$\frac{\$}{\text{flight-hour}} \times \frac{\text{flight time}}{(\text{flight time} + \text{taxi time})} = \frac{\$}{\text{block-hour}}$$

The taxi time element of block time is a system average for the airplane type and is a computational constant in the program. With taxi time constant, the fraction "flight time/(flight time + taxi time)" will always increase with increasing trip distance. Accordingly, the computed maintenance cost block-hour rate also increases with increasing trip distance.

It was previously stated that the cost factors shown in table 2-5 were developed using 1973 schedule P-5.2 data. The DC-8-62 engine labor and material is an exception. During the fourth quarter of 1973 there were significant accounting credits applied to these accounts which seemed to distort the annual data. The cost rates used in this study for these two DC-8-62 elements are averages derived after consulting quarterly reports for 1973 and prior years. It should also be noted that all engine maintenance costs are per airplane and not per engine.

## Fuel and Oil

The fuel costs shown in tables 2-3 and 2-4 were developed by combining two sources of data:

1. Trip fuel vs trip distance curves were developed using actual block times for specific city-pairs multiplied by block fuel rates which were determined from surveys covering typical ranges of trip distances for each fleet type.

2. Average fuel cost determined by dividing CAB form 41 reported costs by total 1973 fuel consumption. The cost rate developed would be slightly higher than actual prices paid for jet fuel because in this case the cost of oil is allocated to the fuel. This is not considered a material distortion.

The resultant block-hour and seat-mile fuel and oil costs are considered representative cost relationships for the trip distances shown. This is opposed to the maintenance, depreciation, insurance, etc., costs which are more accurately described as allocations rather than relationships.

#### INDIRECT OPERATING COSTS

United's planning costs (direct and indirect) are constructed using planned expenses for a future year divided by expected volumes. Prior years' utilization experience is modified according to expected events in the planned year, and anticipated rate increases are applied to resources required. It is an average cost system which is constructed one year in the future. To extend the costs to additional future years, adjustments must be made to the cost mix to reflect price and volume changes. Fuel consumption, for example, changes in direct proportion to increased flying, while General and Administrative (G&A) Expense realizes some economies of scale as organization size increases. G&A is also relatively fixed over short periods of time.

Planning costs are constructed for "business as usual" operation during the year. Actual costs, such as the 1973 DOC's and IOC's tabulated in tables 2-3, 2-4, 2-7 and 2-8, and summarized in tables 2-9 and 2-10, reflect the vagaries of actual operation during a year. These actual costs invite credibility since they are a real historical experience. However, for use as a base to extrapolate several years costs they replicate the patterns of one year throughout the spectrum of analysis. In fact, cost patterns fluctuate from year to year, washing out the distortion of one year's experience approaching "business as usual" in the long run.

Figure 2-2 is a bar chart comparing the total 1973 indirect costs allocated by aircraft type and by distance at two lengths of haul. On a per seat mile basis, these costs vary only slightly between aircraft types. Total cost allocation is more directly a function of aircraft seating capacity than differences between aircraft themselves. Also the relative cost levels at 500 and 1000 nautical miles illustrate the relative proportion of costs that are fixed by departure and are variable by distance.

TABLE 2-7  
INDIRECT OPERATING COSTS

Airplane 737-200	Trip Distance - Nautical Miles				
	200	300	500	750	1000
Landing Fees	48.75	38.24	26.35	18.84	14.72
Aircraft Service	96.25	75.49	52.73	37.20	29.06
Aircraft Control	63.75	50.00	34.46	24.64	19.25
Maintenance, Gnd. Equip. & Facilities	52.50	41.18	28.39	20.29	15.85
Depreciation, Gnd. Equip. & Facilities	53.75	42.16	29.05	20.77	16.23
Inflight Attendants	65.00	65.00	65.00	65.00	65.00
Passenger: Handling	144.33	113.20	78.01	55.78	43.57
Baggage	51.75	40.59	27.97	20.00	15.62
Miscellaneous	10.93	8.57	5.91	4.22	3.30
Sales & Reservations	167.90	131.69	90.76	64.89	50.69
Cargo Handling	16.94	13.28	9.16	6.55	5.11
Passenger Insurance	4.64	5.45	6.26	6.72	7.00
Agency Commission	47.38	48.69	50.63	49.47	49.18
Entertainment	-	-	-	-	-
Publicity & Advertising	28.49	51.55	30.07	29.19	29.02
General & Administrative	78.23	73.14	62.16	57.69	53.86
Passenger Meal Cost	79.38	92.30	63.61	70.36	58.16
Total Indirect Operating Cost	1009.97	890.83	659.41	557.61	475.69

Airplane 727-100	Trip Distance - Nautical Miles				
	300	500	750	1000	1750
Landing Fees	55.00	38.46	28.06	21.91	13.25
Aircraft Service	90.00	62.04	45.00	35.86	21.69
Aircraft Control	51.00	35.66	26.02	20.32	12.29
Maintenance, Gnd. Equip. & Facilities	59.00	41.26	30.10	23.51	14.22
Depreciation, Gnd. Equip. & Facilities	61.00	42.66	31.12	24.30	14.70
Inflight Attendants	69.00	69.00	69.00	69.00	69.00
Passenger: Handling	120.98	84.60	61.72	48.28	29.15
Baggage	43.38	30.34	22.13	17.28	10.45
Miscellaneous	9.16	6.41	4.67	3.65	2.21
Sales & Reservations	140.74	98.42	71.81	56.07	33.91
Cargo Handling	67.47	47.18	34.42	26.85	16.26
Passenger Insurance	6.11	7.12	7.79	8.11	8.53
Agency Commission	45.40	47.48	46.36	44.94	41.74
Entertainment	-	-	-	-	-
Publicity & Advertising	32.73	34.19	34.19	33.85	32.13
General & Administrative	82.27	69.82	63.37	59.02	53.17
Passenger Meal Cost	96.54	67.51	66.24	63.09	51.65
Total Indirect Operating Cost	1029.71	783.05	643.55	547.09	404.41

Airplane 707-200	Trip Distance - Nautical Miles				
	300	500	750	1000	1750
Landing Fees	59.40	41.67	30.15	22.51	14.54
Aircraft Service	95.00	66.67	48.24	36.10	22.57
Aircraft Control	60.00	36.42	26.63	20.24	12.56
Maintenance, Gnd. Equip. & Facilities	64.36	45.14	33.66	25.79	15.69
Depreciation, Gnd. Equip. & Facilities	66.34	46.63	34.67	26.59	16.11
Inflight Attendants	81.00	81.00	81.00	81.00	81.00
Passenger: Handling	148.84	104.41	76.64	59.64	36.14
Baggage	53.39	37.44	27.69	21.22	12.96
Miscellaneous	11.77	7.90	5.72	4.40	2.74
Sales & Reservations	173.15	111.47	82.89	64.41	40.49
Cargo Handling	92.35	64.65	46.72	36.04	22.57
Passenger Insurance	7.50	8.70	9.43	10.01	10.61
Agency Commission	67.13	70.73	69.13	67.13	63.13
Entertainment	-	-	-	-	-
Publicity & Advertising	40.19	41.19	41.00	41.79	39.67
General & Administrative	92.55	77.13	71.17	66.79	59.63
Passenger Meal Cost	122.41	82.53	77.44	74.41	60.75
Total Indirect Operating Cost	1157.11	943.00	727.10	612.60	471.79



TABLE 2-7 (Cont.)  
INDIRECT OPERATING COSTS  
\$/Block Hour

Airplane	DC-8-20	Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Landing Fees		53.69	31.01	21.86	16.88	13.72
Aircraft Service		140.27	81.01	57.10	44.09	35.85
Aircraft Control		34.23	19.77	13.93	10.76	8.75
Maintenance, Gnd. Equip. & Facilities		57.72	33.33	23.50	18.14	14.75
Depreciation, Gnd. Equip. & Facilities		59.73	34.50	24.32	18.78	15.27
Inflight Attendants		90.00	90.00	90.00	90.00	90.00
Passenger: Handling		94.67	54.67	38.64	29.76	24.20
Baggage		33.95	19.60	13.82	10.67	8.68
Miscellaneous		7.17	4.14	2.92	2.25	1.83
Sales & Reservations		110.13	63.60	44.84	34.62	28.15
Cargo Handling		70.26	40.57	28.60	22.08	17.96
Passenger Insurance		7.69	3.88	2.39	1.67	1.33
Agency Commission		62.13	62.40	58.03	56.91	53.93
Entertainment		4.45	4.45	4.45	4.56	16.28
Publicity & Advertising		37.04	37.17	34.23	33.70	32.01
General & Administrative		90.11	75.75	69.50	66.65	64.76
Passenger Meal Cost		76.89	68.67	59.80	57.40	47.81
Total Indirect Operating Cost		1030.13	729.52	594.21	508.92	463.78

Airplane	DC-8-51/-52	Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Landing Fees		54.05	31.13	21.92	16.91	13.75
Aircraft Service		141.22	81.32	57.26	44.19	35.91
Aircraft Control		34.46	19.84	13.97	10.78	8.76
Maintenance, Gnd. Equip. & Facilities		58.11	33.46	23.56	18.18	14.79
Depreciation, Gnd. Equip. & Facilities		60.14	34.63	24.30	18.82	15.29
Inflight Attendants		90.00	90.00	90.00	90.00	90.00
Passenger: Handling		95.31	54.89	38.65	29.82	24.24
Baggage		34.18	19.68	13.86	10.69	8.69
Miscellaneous		7.22	4.16	2.93	2.26	1.84
Sales & Reservations		110.88	63.85	44.96	34.69	28.20
Cargo Handling		70.73	40.73	28.68	22.13	17.99
Passenger Insurance		7.96	3.96	2.47	1.84	1.50
Agency Commission		63.54	63.64	59.12	57.93	54.86
Entertainment		4.30	4.30	4.30	4.41	16.16
Publicity & Advertising		37.96	37.97	35.00	34.35	32.60
General & Administrative		88.26	73.68	67.27	64.30	62.35
Passenger Meal Cost		77.41	68.94	60.04	57.52	47.89
Total Indirect Operating Cost		1035.63	731.28	596.49	509.87	463.35

Airplane	DC-8-61	Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Landing Fees		64.43	37.07	26.16	20.21	16.44
Aircraft Service		147.65	84.94	60.05	46.32	37.67
Aircraft Control		34.23	19.69	13.98	10.74	8.73
Maintenance, Gnd. Equip. & Facilities		69.11	39.77	28.07	21.68	17.64
Depreciation, Gnd. Equip. & Facilities		71.14	40.93	28.98	22.32	18.15
Inflight Attendants		107.00	107.00	107.00	107.00	107.00
Passenger: Handling		110.34	63.48	44.99	34.61	28.14
Baggage		39.56	22.70	16.06	12.26	10.09
Miscellaneous		8.36	4.81	3.39	2.67	2.13
Sales & Reservations		122.36	73.88	52.11	40.67	33.75
Cargo Handling		74.44	42.01	29.41	22.64	18.74
Passenger Insurance		10.13	11.66	12.75	12.72	12.92
Agency Commission		71.91	71.91	70.36	74.56	70.90
Entertainment		4.99	4.99	4.99	4.40	16.10
Publicity & Advertising		48.93	48.93	45.11	44.09	42.14
General & Administrative		97.91	81.09	73.31	72.44	69.15
Passenger Meal Cost		92.92	79.00	69.09	66.16	54.12
Total Indirect Operating Cost		1106.63	647.70	601.10	601.14	561.95

TABLE 2-7 (Cont.)

## INDIRECT OPERATING COSTS

\$/Block Hour

Airplane	DC-8-62	Trip Distance - Nautical Miles				
		500	1000	2000	3000	4500
Landing Fees		63.58	36.92	20.21	13.89	9.45
Aircraft Service		149.67	86.92	47.58	32.71	22.24
Aircraft Control		33.77	19.62	10.74	7.38	5.02
Maintenance, Gnd. Equip. & Facilities		68.21	39.62	21.68	14.91	10.14
Depreciation, Gnd. Equip. & Facilities		70.20	40.77	22.32	15.34	10.43
Inflight Attendants		90.00	90.00	90.00	90.00	90.00
Passenger: Handling		88.93	51.65	28.27	19.43	13.22
Baggage		31.89	18.52	10.14	6.97	4.74
Miscellaneous		6.74	3.91	2.14	1.47	1.00
Sales & Reservations		103.46	60.08	32.89	22.61	15.38
Cargo Handling		60.64	35.22	19.28	13.25	9.01
Passenger Insurance		7.89	9.16	10.03	10.34	10.55
Agency Commission		63.74	64.38	59.03	54.74	55.84
Entertainment		5.38	5.38	7.49	15.36	12.17
Publicity & Advertising		38.04	38.38	34.98	32.57	33.28
General & Administrative		91.01	73.81	64.35	61.39	59.07
Passenger Meal Cost		88.00	61.64	51.76	44.97	30.59
Total Indirect Operating Cost		1061.15	735.98	532.89	457.33	392.13

Airplane	DC-10-10	Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Landing Fees		86.54	51.72	36.89	28.66	23.44
Aircraft Service		107.69	124.14	88.52	68.79	56.25
Aircraft Control		32.69	19.54	13.93	10.83	8.85
Maintenance, Gnd. Equip. & Facilities		92.95	55.56	39.62	30.79	25.17
Depreciation, Gnd. Equip. & Facilities		96.15	57.47	40.98	31.85	26.04
Inflight Attendants		216.00	216.00	216.00	216.00	216.00
Passenger: Handling		160.42	95.88	68.37	53.13	43.45
Baggage		57.52	34.38	24.52	19.05	15.58
Miscellaneous		12.14	7.26	5.17	4.02	3.29
Sales & Reservations		186.62	111.54	79.54	61.81	50.54
Cargo Handling		146.54	87.59	62.46	48.54	39.69
Passenger Insurance		12.40	14.83	15.86	16.44	16.80
Agency Commission		100.24	104.21	98.03	96.74	92.21
Entertainment		4.32	4.32	4.32	6.44	16.30
Publicity & Advertising		60.80	63.07	58.61	57.92	55.43
General & Administrative		139.17	116.15	106.49	102.30	98.90
Passenger Meal Cost		179.23	129.19	113.81	113.60	95.08
Total Indirect Operating Cost		1791.42	1292.65	1073.12	966.91	883.02

Airplane	747-100	Trip Distance - Nautical Miles				
		500	1000	2000	3000	4000
Landing Fees		141.89	96.31	48.30	33.58	25.65
Aircraft Service		228.75	139.16	77.87	54.14	41.36
Aircraft Control		31.88	19.39	10.95	7.54	5.76
Maintenance, Gnd. Equip. & Facilities		161.28	92.40	51.70	35.95	27.46
Depreciation, Gnd. Equip. & Facilities		166.87	95.44	52.40	37.13	28.36
Inflight Attendants		237.00	237.00	237.00	237.00	237.00
Passenger: Handling		191.54	116.53	65.21	45.34	34.63
Baggage		68.68	41.75	23.39	16.26	12.42
Miscellaneous		14.50	8.02	4.94	3.43	2.60
Sales & Reservations		208.36	135.56	75.88	52.74	40.29
Cargo Handling		136.66	113.56	63.54	44.19	33.75
Passenger Insurance		14.36	15.21	20.22	21.25	21.64
Agency Commission		120.89	107.97	110.21	112.46	114.52
Entertainment		4.64	4.64	6.77	16.55	19.44
Publicity & Advertising		73.23	77.37	71.73	67.75	65.16
General & Administrative		176.63	141.36	122.27	116.19	111.46
Passenger Meal Cost		211.77	164.43	138.30	108.22	88.74
Total Indirect Operating Cost		2292.46	1631.23	1192.52	1062.10	961.21

TABLE 2-8

## INDIRECT OPERATING COSTS

c/Avail-Seat-Naut-Mile

Airplane 737-200	Trip Distance - Nautical Miles				
	200	300	500	750	1000
Landing Fees	.210	.140	.084	.056	.042
Aircraft Service	.416	.277	.166	.111	.083
Aircraft Control	.275	.184	.110	.073	.055
Maintenance, Gnd. Equip. & Facilities	.227	.151	.091	.060	.045
Depreciation, Gnd. Equip. & Facilities	.232	.155	.093	.062	.046
Inflight Attendants	.281	.239	.208	.194	.186
Passenger: Handling	.623	.416	.249	.166	.125
Baggage	.224	.149	.089	.060	.045
Miscellaneous	.047	.031	.019	.013	.009
Sales & Reservations	.725	.483	.290	.193	.145
Cargo Handling	.073	.049	.029	.020	.016
Passenger Insurance	.020	.020	.020	.020	.020
Agency Commission	.205	.180	.162	.147	.141
Entertainment	-	-	-	-	-
Publicity & Advertising	.123	.189	.096	.087	.083
General & Administrative	.338	.269	.199	.172	.154
Passenger Meal Cost	.343	.339	.203	.228	.166
Total Indirect Operating Cost	4.362	3.271	2.108	1.662	1.360

Airplane 727-100	Trip Distance - Nautical Miles				
	300	500	750	1000	1750
Landing Fees	.190	.114	.076	.057	.033
Aircraft Service	.310	.186	.124	.093	.053
Aircraft Control	.176	.105	.070	.053	.030
Maintenance, Gnd. Equip. & Facilities	.203	.122	.081	.061	.035
Depreciation, Gnd. Equip. & Facilities	.210	.126	.084	.063	.036
Inflight Attendants	.238	.204	.187	.179	.169
Passenger: Handling	.417	.250	.167	.125	.072
Baggage	.150	.090	.060	.045	.026
Miscellaneous	.032	.019	.013	.009	.005
Sales & Reservations	.485	.291	.194	.146	.083
Cargo Handling	.233	.140	.093	.070	.040
Passenger Insurance	.021	.021	.021	.021	.021
Agency Commission	.156	.140	.125	.116	.120
Entertainment	-	-	-	-	-
Publicity & Advertising	.113	.101	.092	.088	.079
General & Administrative	.224	.207	.171	.154	.130
Passenger Meal Cost	.333	.200	.121	.164	.117
Total Indirect Operating Cost	3.551	2.316	1.739	1.444	1.061

Airplane 727-200	Trip Distance - Nautical Miles				
	300	500	750	1000	1750
Landing Fees	.163	.098	.065	.049	.029
Aircraft Service	.261	.156	.104	.078	.045
Aircraft Control	.139	.083	.055	.042	.024
Maintenance, Gnd. Equip. & Facilities	.127	.106	.071	.052	.030
Depreciation, Gnd. Equip. & Facilities	.182	.109	.073	.065	.031
Inflight Attendants	.241	.206	.190	.181	.172
Passenger: Handling	.409	.245	.162	.122	.072
Baggage	.146	.089	.059	.044	.026
Miscellaneous	.031	.019	.013	.009	.005
Sales & Reservations	.475	.290	.190	.142	.081
Cargo Handling	.262	.162	.101	.076	.043
Passenger Insurance	.021	.021	.021	.021	.021
Agency Commission	.145	.166	.151	.144	.139
Entertainment	-	-	-	-	-
Publicity & Advertising	.116	.100	.090	.087	.077
General & Administrative	.236	.200	.164	.137	.116
Passenger Meal Cost	.336	.201	.122	.165	.117
Total Indirect Operating Cost	3.323	2.222	1.608	1.322	1.000

TABLE 2-8 (Cont.)

## INDIRECT OPERATING COSTS

c/Avail-Seat-Naut-Mile

Airplane	DC-8-20	Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Landing Fees		.135	.066	.044	.033	.027
Aircraft Service		.347	.173	.116	.087	.069
Aircraft Control		.085	.042	.028	.021	.017
Maintenance, Gnd. Equip. & Facilities		.143	.071	.048	.036	.029
Depreciation, Gnd. Equip. & Facilities		.148	.074	.049	.037	.030
Inflight Attendants		.222	.193	.182	.177	.174
Passenger: Handling		.234	.117	.078	.049	.047
Baggage		.084	.040	.028	.021	.017
Miscellaneous		.018	.009	.006	.004	.004
Sales & Reservations		.172	.136	.091	.061	.064
Cargo Handling		.174	.087	.058	.042	.035
Passenger Insurance		.019	.112	.019	.019	.011
Agency Commission		.154	.134	.117	.112	.104
Entertainment		.011	.009	.009	.013	.021
Publicity & Advertising		.092	.080	.070	.066	.062
General & Administrative		.223	.162	.141	.131	.125
Passenger Meal Cost		.190	.147	.121	.113	.095
Total Indirect Operating Cost		2.551	1.551	1.205	1.140	.938

Airplane	DC-8-51/-E2	Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Landing Fees		.131	.065	.044	.033	.026
Aircraft Service		.341	.171	.114	.086	.068
Aircraft Control		.082	.042	.028	.021	.018
Maintenance, Gnd. Equip. & Facilities		.141	.070	.047	.035	.028
Depreciation, Gnd. Equip. & Facilities		.145	.073	.048	.036	.030
Inflight Attendants		.218	.199	.179	.174	.171
Passenger: Handling		.220	.115	.077	.048	.046
Baggage		.083	.041	.028	.021	.017
Miscellaneous		.017	.009	.006	.004	.004
Sales & Reservations		.258	.134	.086	.067	.064
Cargo Handling		.171	.085	.057	.043	.034
Passenger Insurance		.019	.112	.019	.019	.011
Agency Commission		.154	.134	.117	.112	.104
Entertainment		.010	.009	.009	.012	.021
Publicity & Advertising		.092	.080	.070	.066	.062
General & Administrative		.213	.165	.134	.124	.115
Passenger Meal Cost		.187	.145	.119	.111	.091
Total Indirect Operating Cost		2.503	1.536	1.185	1.021	.813

Airplane	DC-8-61	Trip Distance - Nautical Miles				
		500	1000	1500	2000	2500
Landing Fees		.116	.055	.039	.029	.023
Aircraft Service		.266	.123	.089	.066	.051
Aircraft Control		.062	.031	.021	.015	.012
Maintenance, Gnd. Equip. & Facilities		.125	.061	.040	.031	.025
Depreciation, Gnd. Equip. & Facilities		.128	.064	.043	.032	.026
Inflight Attendants		.193	.169	.155	.154	.151
Passenger: Handling		.190	.109	.066	.050	.040
Baggage		.071	.036	.024	.018	.014
Miscellaneous		.015	.007	.005	.004	.003
Sales & Reservations		.141	.116	.077	.067	.064
Cargo Handling		.137	.066	.044	.033	.027
Passenger Insurance		.011	.111	.011	.011	.011
Agency Commission		.140	.112	.112	.112	.107
Entertainment		.009	.007	.006	.009	.010
Publicity & Advertising		.083	.077	.067	.064	.061
General & Administrative		.217	.177	.159	.151	.146
Passenger Meal Cost		.151	.114	.111	.108	.105
Total Indirect Operating Cost		2.117	1.631	1.253	1.056	.856

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TABLE 2-B (Cont.)

INDIRECT OPERATING COSTS  
\$/Avail-Seat-Naut-Mile

Airplane	LC-8-62	Trip Distance - Nautical Miles				
		500	1000	2000	3000	4500
Landing Fees		.150	.075	.038	.025	.017
Aircraft Service		.354	.177	.088	.059	.039
Aircraft Control		.080	.040	.020	.013	.009
Maintenance, Gnd. Equip. & Facilities		.161	.081	.040	.027	.018
Depreciation, Gnd. Equip. & Facilities		.166	.083	.041	.028	.018
Inflight Attendants		.213	.103	.052	.034	.023
Passenger: Handling		.210	.105	.053	.035	.023
Baggage		.075	.038	.019	.013	.008
Miscellaneous		.016	.008	.004	.003	.002
Sales & Reservations		.245	.122	.061	.041	.027
Cargo Handling		.143	.072	.036	.024	.016
Passenger Insurance		.019	.019	.019	.019	.019
Agency Commission		.151	.131	.110	.099	.084
Entertainment		.013	.011	.014	.008	.007
Publicity & Advertising		.090	.078	.065	.050	.040
General & Administrative		.215	.150	.120	.111	.104
Passenger Meal Cost		.208	.126	.097	.081	.064
Total Indirect Operating Cost		2.500	1.400	.980	.627	.493

Airplane	DC-10-10	Trip Distance - Nautical Miles				
		500	1000	1500	2000	3500
Landing Fees		.116	.058	.030	.020	.013
Aircraft Service		.278	.139	.093	.069	.055
Aircraft Control		.044	.022	.015	.011	.009
Maintenance, Gnd. Equip. & Facilities		.124	.062	.041	.031	.025
Depreciation, Gnd. Equip. & Facilities		.128	.064	.043	.032	.026
Inflight Attendants		.289	.141	.086	.058	.039
Passenger: Handling		.214	.107	.072	.054	.040
Baggage		.077	.039	.026	.019	.015
Miscellaneous		.016	.008	.005	.004	.003
Sales & Reservations		.240	.125	.083	.062	.048
Cargo Handling		.196	.099	.065	.049	.039
Passenger Insurance		.017	.017	.017	.017	.017
Agency Commission		.134	.116	.102	.098	.091
Entertainment		.006	.005	.004	.006	.016
Publicity & Advertising		.081	.071	.061	.056	.056
General & Administrative		.186	.130	.111	.103	.090
Passenger Meal Cost		.239	.144	.119	.115	.094
Total Indirect Operating Cost		2.374	1.445	1.180	.875	.675

Airplane	747-100	Trip Distance - Nautical Miles				
		500	1000	2000	3000	4500
Landing Fees		.144	.072	.036	.024	.016
Aircraft Service		.232	.116	.058	.039	.026
Aircraft Control		.032	.016	.009	.006	.004
Maintenance, Gnd. Equip. & Facilities		.114	.057	.029	.019	.013
Depreciation, Gnd. Equip. & Facilities		.119	.060	.030	.020	.014
Inflight Attendants		.240	.120	.060	.040	.027
Passenger: Handling		.240	.120	.060	.040	.027
Baggage		.070	.035	.017	.011	.007
Miscellaneous		.016	.008	.004	.003	.002
Sales & Reservations		.240	.120	.060	.040	.027
Cargo Handling		.190	.095	.047	.031	.021
Passenger Insurance		.016	.016	.016	.016	.016
Agency Commission		.122	.112	.099	.091	.080
Entertainment		.005	.004	.004	.004	.004
Publicity & Advertising		.074	.064	.059	.054	.049
General & Administrative		.123	.113	.099	.093	.080
Passenger Meal Cost		.214	.117	.058	.039	.026
Total Indirect Operating Cost		2.312	1.340	.910	.620	.450

TABLE 2-9  
1973 OPERATING COSTS SUMMARY - \$/BLOCK-HOUR

Trip Distance - (Naut.Mi.)	Total DOC's - \$/Block-Hour (rounded)								
	737- 200	727- 100	727- 200	DC-8- 20	DC-8- 51/-52	DC-8- 61	DC-8- 62	DC-10- 10	747- 100
200	594	—	—	—	—	—	—	—	—
300	607	676	727	—	—	—	—	—	—
500	622	685	732	845	876	945	1036	1337	1605
750	634	694	739	—	—	—	—	—	—
1000	640	698	745	855	886	944	1013	1372	1614
1500	—	—	—	864	893	949	—	1397	—
1750	—	708	758	—	—	—	—	—	—
2000	—	—	—	872	899	954	1023	1416	1658
2500	—	—	—	878	905	959	—	1432	—
3000	—	—	—	—	—	—	1037	—	1694
4000	—	—	—	—	—	—	—	—	1722
4500	—	—	—	—	—	—	1054	—	—

Trip Distance - (Naut.Mi.)	Total IOC's - \$/Block-Hour (rounded)								
	737- 200	727- 100	727- 200	DC-8- 20	DC-8- 51/-52	DC-8- 61	DC-8- 62	DC-10- 10	747- 100
200	1010	—	—	—	—	—	—	—	—
300	891	1030	1233	—	—	—	—	—	—
500	660	783	946	1030	1036	1181	1061	1791	2228
750	558	644	778	—	—	—	—	—	—
1000	476	556	684	730	731	844	736	1293	1610
1500	—	—	—	595	595	691	—	1073	—
1750	—	424	529	—	—	—	—	—	—
2000	—	—	—	529	529	616	533	967	1193
2500	—	—	—	484	483	563	—	883	—
3000	—	—	—	—	—	—	457	—	1008
4000	—	—	—	—	—	—	—	—	902
4500	—	—	—	—	—	—	392	—	—

Trip Distance - (Naut.Mi.)	Total Operating Costs (DOC's + IOC's) - \$/Block-Hour (rounded)								
	737- 200	727- 100	727- 200	DC-8- 20	DC-8- 51/-52	DC-8- 61	DC-8- 62	DC-10- 10	747- 100
200	1604	—	—	—	—	—	—	—	—
300	1498	1706	1960	—	—	—	—	—	—
500	1282	1468	1678	1875	1912	2126	2097	3128	3833
750	1192	1388	1517	—	—	—	—	—	—
1000	1116	1254	1429	1585	1617	1788	1740	2665	3224
1500	—	—	—	1459	1488	1640	—	2470	—
1750	—	1132	1287	—	—	—	—	—	—
2000	—	—	—	1401	1428	1570	1556	2383	2851
2500	—	—	—	1362	1388	1522	—	2315	—
3000	—	—	—	—	—	—	1494	—	2702
4000	—	—	—	—	—	—	—	—	2624
4500	—	—	—	—	—	—	1446	—	—

TABLE 2-10

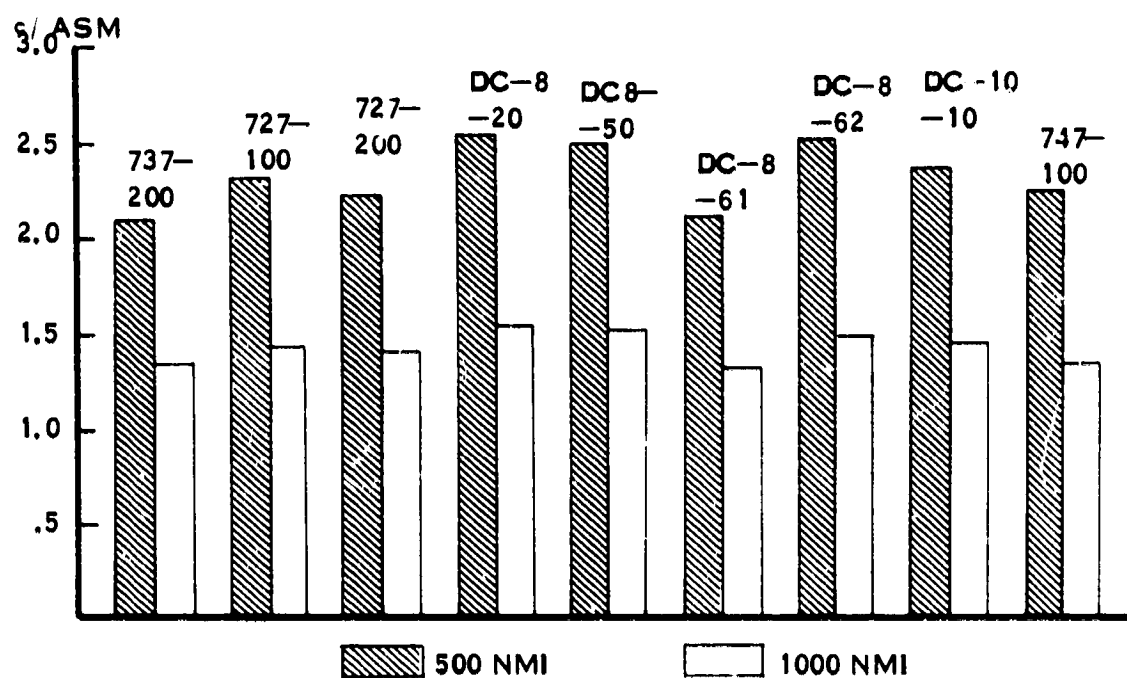
## 1973 OPERATING COSTS SUMMARY - c/AVAIL-SEAT-NAUT-MILE

Trip Distance - (Naut.Mi.)	Total DOC's - c/Avail-Seat-Naut-Mile								
	737- 200	727- 100	727- 200	DC-8- 20	DC-8- 51/-52	DC-8- 61	DC-8- 62	DC-10- 10	747- 100
200	2.566	—	—	—	—	—	—	—	—
300	2.230	2.330	1.994	—	—	—	—	—	—
500	1.989	2.026	1.721	2.089	2.118	1.703	2.449	1.786	1.627
750	1.887	1.876	1.599	—	—	—	—	—	—
1000	1.831	1.811	1.528	1.831	1.858	1.479	2.063	1.534	1.344
1500	—	—	—	1.747	1.775	1.401	—	1.458	—
1750	—	1.735	1.466	—	—	—	—	—	—
2000	—	—	—	1.714	1.734	1.369	1.902	1.427	1.234
2500	—	—	—	1.700	1.719	1.353	—	1.413	—
3000	—	—	—	—	—	—	1.871	—	1.209
4000	—	—	—	—	—	—	—	—	1.207
4500	—	—	—	—	—	—	1.862	—	—

Trip Distance - (Naut.Mi.)	Total IOC's - c/Avail-Seat-Naut-Mile								
	737- 200	727- 100	727- 200	DC-8- 20	DC-8- 51/-52	DC-8- 61	DC-8- 62	DC-10- 10	747- 100
200	4.362	—	—	—	—	—	—	—	—
300	3.271	3.551	3.383	—	—	—	—	—	—
500	2.108	2.316	2.220	2.551	2.503	2.128	2.509	2.394	2.259
750	1.662	1.739	1.682	—	—	—	—	—	—
1000	1.360	1.444	1.404	1.561	1.536	1.321	1.499	1.445	1.342
1500	—	—	—	1.205	1.185	1.023	—	1.122	—
1750	—	1.041	1.024	—	—	—	—	—	—
2000	—	—	—	1.040	1.021	.885	.992	.975	.888
2500	—	—	—	.936	.919	.795	—	.872	—
3000	—	—	—	—	—	—	.827	—	.720
4000	—	—	—	—	—	—	—	—	.632
4500	—	—	—	—	—	—	.693	—	—

Trip Distance - (Naut.Mi.)	Total Operating Costs (DOC's + IOC's) - c/Avail-Seat-Naut-Mile								
	737- 200	727- 100	727- 200	DC-8- 20	DC-8- 51/-52	DC-8- 61	DC-8- 62	DC-10- 10	747- 100
200	6.928	—	—	—	—	—	—	—	—
300	5.501	5.881	5.377	—	—	—	—	—	—
500	4.097	4.342	3.941	4.640	4.621	2.831	4.958	4.180	3.886
750	3.549	3.615	3.281	—	—	—	—	—	—
1000	3.191	3.255	2.932	3.392	3.394	2.800	3.562	2.679	2.686
1500	—	—	—	2.952	2.960	2.424	—	2.580	—
1750	—	2.776	2.490	—	—	—	—	—	—
2000	—	—	—	2.754	2.755	2.254	2.894	2.402	2.122
2500	—	—	—	2.636	2.638	2.148	—	2.285	—
3000	—	—	—	—	—	—	2.698	—	1.929
4000	—	—	—	—	—	—	—	—	1.839
4500	—	—	—	—	—	—	2.555	—	—

Figure 2-2  
1973 INDIRECT OPERATING COSTS  
c/Available-Seat-Nautical-Mile





While United's system of grouping indirect costs is similar to the CAB cost categories, internal records are used to break down general accounting cost groups into cost categories which tend to fluctuate with a common variable. Table 2-11 provides a comparison of the CAB indirect operating cost accounts and United's indirect operating cost categories. The explanatory variable used to develop each of United's indirect costs appears in the right-hand column.

CAB 5200 and 5300 accounts are grouped together in United's planning cost system. Burden amounts are added to the direct accounts to which they relate and spread according to the allocation method used for the direct account. The CAB 6300 account is applied to the 6100 aircraft servicing costs and the 6200 traffic servicing accounts in a similar fashion.

The CAB 5500 passenger service account is broken down into inflight attendants, passenger meal service, passenger liability insurance and miscellaneous passenger service expenses. The 6100 account is separated into landing fees, aircraft cleaning, and aircraft fueling. The 6200 account is subdivided by passenger handling, baggage handling, and cargo handling. The 6500 account, reservations and sales, is separated into agency commissions, passenger sales and reservations, and freight sales and reservations. Similarly, 6600 advertising and publicity, is divided into passenger and freight expenses.

CAB 6800, general and administrative, and CAB 7000, depreciation-ground property and equipment, are common with United's costing categories.

Table 2-12 outlines the indirect cost rates used to compile the extensive tabulation of 1973 costs in tables 2-7 and 2-8. Direct costs have been included in table 2-12 so that when combined with the indirect cost rates and with system or aircraft lift and load statistics, total trip costs of United's aircraft can be calculated. The paragraphs that follow discuss the indirect cost elements; column numbers refer to table 2-12 columns.

### Landing Fees

Landing fees (col. 2) are related to aircraft departures, weighted by maximum landing gross weights. Landing fees are currently assessed on the aircraft maximum landing weight (a few airports charge on maximum takeoff gross weight). Hawaiian fees are 69¢ higher than the corresponding domestic landing rate to reflect that nearly all Hawaiian trips connect with large mainland airports with higher than average landing fees. In estimating future landing fee costs, changes in airport use, such as changes to frequency and size, must be taken into account. Total airport costs are divided by forecast departures in determining airline fees.

Significant changes in the use of an airport would cause adjustment to the fee structure. For reference purposes the maximum takeoff and landing weights for United's aircraft are tabulated in table 2-13.

### Aircraft Servicing

Aircraft servicing (col. 4) relates to the cleaning and fueling activities between aircraft trips. Separate staffs are required for each activity. Cost allocations are made by aircraft type on the basis of man-minute standards which are updated periodically. The relative standards by fleet for 1973, using the 737-200 as a base of 1.0, were:

	<u>Cleaning</u>		<u>Servicing/ Fueling</u>	
	<u>Mainland</u>	<u>Hawaii</u>	<u>Mainland</u>	<u>Hawaii</u>
747-100	4.4	6.5	4.8	5.2
DC-10-10	4.1	-	4.2	-
DC-8-62	1.8	3.9	3.2	3.4
DC-8-61	2.6	5.2	2.9	3.1
DC-8-50	1.9	5.2	2.9	3.1
DC-8-20	1.9	-	2.9	-
727-200	1.4	-	1.2	-
727-100	1.0	-	1.2	-
737-200 (base)	1.0	-	1.0	-

Cleaning standards are a function of the number of seats per aircraft, and the average length of haul of each aircraft type. Fueling standards are related to the tank capacity of the aircraft type.

Hawaiian servicing cost rates (table 2-12) are inflated, both by the trip length, indicated by the significantly higher servicing weights for each aircraft type, and by a 7.5% average salary differential.

### Aircraft Control

Included in the aircraft control costs (col. 5) are dispatch meteorology and indirect flight operations expenses. Total expense level is a function of system departures, regardless of aircraft type.

### Ground Property and Equipment Maintenance

Maintenance expense for ground equipment and facilities (col. 6) is allocated by weighted departures. Maintenance requirements are a function of gate and equipment usage and vary with aircraft size as well as departure frequency. Maximum gross landing weights are used as the size weighting factor, as in the case of landing fees.

### Depreciation and Amortization - Ground Property and Equipment

Depreciation and amortization on ground property and equipment (cols. 7 and 8) are allocated in the same manner as maintenance requirements, reflecting the support requirements by aircraft type and by departure frequency.

### Inflight Attendant

Flight attendant salary (col. 12) is a contractual agreement between the union and the airline. The number of hours worked is measured on block to block time. United uses a variable complement staffing policy, so that the number of attendants per cabin is a function of (1) the number of saleable seats, (2) the forecasted load, (3) cabin efficiency and (4) contractual agreement. The 1973 costs were spread according to average crew complements by aircraft type and block hour experience. The average cabin complement during 1973 was:

	<u>Mainland</u>	<u>Hawaii</u>
747-100	11.5*	14.4*
DC-10-10	10.5*	-
DC-8-62	4.35	4.5
DC-8-61	5.2	6.0
DC-8-50	4.35	4.5
DC-8-20	4.35	-
727-200	4.30	-
727-100	3.35	-
737-200	3.15	-

\* includes inflight supervisor.

### Passenger Costs

Passenger handling, baggage handling, sales and reservations, and miscellaneous passenger service are related to the total number of passengers boarded. Baggage handling weights by aircraft type are used to isolate baggage related expense from cargo expense. Charges per passenger are not made by aircraft; instead the system average baggage rate is used. (Col. 17)

### Passenger Liability Insurance

Passenger liability insurance expense (col. 18) is negotiated on the basis of revenue passenger miles flown.

### Agency Commission

Agency commission liability (col. 20) is based upon ticket price. The system average ratio of total agency commission to total passenger revenue for 1973 was 3.45%.

### Publicity and Advertising

Separate accounts are kept on passenger and freight related publicity and advertising (col. 20). Planned expenditures are based upon forecast revenues for the year. In 1973, advertising and publicity for passenger traffic was 2.02% of revenue and freight advertising and publicity was .78% of revenue.

### Inflight Entertainment

Expenses for movie and audio flights are included in inflight entertainment expenses. While all 747-100's, DC-10-10's, DC-8-62's, DC-8-61's, DC-8-50's and DC-8-20's are equipped with audio and projection equipment, entertainment is actually provided only on long flights. The 1973 contract between United and one of its entertainment system vendors charged an annual fee for equipment maintenance and service. Film rental was based on the number of movie flights, and earphone cleaning costs were a function of the number of movie and audio flights.

The expenses allocated in table 2-12 for inflight entertainment consist of a daily equipment rental charge, col. 23, (prorated by trip time and average aircraft utilization) and a film or audio tape service charge for entertainment flights (col. 21). Trips 1750 nautical miles or greater were assessed a \$10 audio charge. Trips 2500 nautical miles or greater were assessed a \$69 film charge.

Equipment rental cost is based on the number of movie projectors aboard each aircraft at \$12.75 per projector, per day. The DC-8-20, DC-8-50, DC-8-61 and DC-10-10 have 3 projectors. The DC-8-62 and the 747-100 have 4 projectors.

### Cargo Handling Costs

Cargo handling costs (col. 19) are allocated by cargo tons boarded. Manpower requirements vary with the type of cargo boarded and the aircraft type. Man-minute weighting factors by aircraft type were compiled for the domestic air freight rate investigation (ref. i). Containerization of the belly pits, particularly in the case of wide bodies, allows significant improvements in loading time requirements. The 1973 cargo handling weighting factors were:

	<u>Mainland</u>	<u>Hawaii</u>
747-100	1.81	1.84
DC-10-10	1.92	-
DC-8-62	3.09	3.49
DC-8-61	3.46	3.46
DC-8-50	3.61	3.60
DC-8-20	3.61	-
727-200	3.67	-
727-100	3.55	-
737-200	4.26	-

In addition to the physical loading expense, \$38.60 per 1000 kg (\$35 per ton) of freight is charged for customer service paperwork and accounting expense.

### Freight Sales Costs

Sales expense is incurred only by the freight portion of cargo and amounted to \$8.05 per 1000 kg (\$7.30 per ton) of freight handled in 1973. Freight repre-

sented about 2/3 of all belly cargo, therefore, freight sales expense (col. 19) in relation to total belly cargo was \$5.35 per 1000 kg (\$4.85 per ton) of cargo boarded.

### Passenger Meal Expense

Passenger meal costs (col. 22) are a function of trip time and class of service for each passenger boarded.

### General and Administrative Expense

The general and administrative expense (col. 30) is generally related to the total cash expenditures. For this study lease expense has been treated as a non-cash item and was not used in allocating overhead amounts. In 1973, General and Administrative expense was 5.72% of cash expenditure excepting leases and General and Administrative expenses. Table 2-12 segregates total expenses into cash and non-cash items for purposes of allocating this cost.

Figure 2-3 illustrates the relative magnitude of direct costs and indirect costs allocated to a 1000 nautical mile trip for each of the study aircraft. Notice that the variation in total costs is more related to the variability of direct costs.

TABLE 2-11  
COMPARISON OF CAB AND UNITED INDIRECT COST CATEGORIES

CAB Indirect Operating Cost Categories	United Indirect Operating Costs	United Cost Allocation Base
5200 Direct Maintenance - Ground Prop. & Equipment	Ground Equipment Maintenance	Departures/Wtd. by Max. Allowable Landing Wt.
5300 Applied Maint. Burden - Ground Prop. & Equipment		Wtd. by Direct Cost Allocation
5500 Passenger Service	Inflight Attendants Passenger Meal Service Passenger Liability Insurance Misc. Passenger Service	Block Hours/Wtd. by Average Crew Complement Trip Length & Class of Service Passenger Miles Revenue Passengers Boarded
6100 Aircraft Servicing	Landing Fees Aircraft Servicing: Cleaning Fueling	Departures/Wtd. by Max. Allowable Landing Wt. Departures/Wtd. by Direct Labor Hours Departures/Wtd. by UA Industrial Engrg. Standards
6200 Traffic Servicing	Passenger Handling Ramp: Baggage Cargo	Revenue Passengers Boarded Revenue Passengers Boarded/Wtd. by UA Industrial Engrg. Standards Cargo Tons Boarded
6300 Servicing Administration		Wtd. by Direct Cost Allocation
6500 Reservations & Sales	Agency Commission Sales & Reservations: Passenger Freight	Passenger Revenue Revenue Passengers Boarded Cargo Tons Boarded
6600 Advertising & Publicity	Passenger Freight	Passenger Revenue Freight Revenue
6800 General & Administrative	General & Administrative	Direct & Indirect Cash Costs Allocated (Less G & A)
7000 Depreciation - Ground Prop. & Equipment	Depreciation & Amortization - Ground Prop. & Equipment	Departures/Wtd. by Max. Allowable Landing Wt.

TABLE 2-12  
TOTAL OPERATING COSTS  
1973 Actual Costs as Allocated

Cost per Departure									
Aircraft Type	Landing Fees	Departure Fuel*	A/C Servicing	A/C Controlling	Ground Eqpt. & Facil. Maintce.	Ground Eqpt. & Facil.		Total Cash Costs (2)thru(6)	Total Costs (2)thru(8)
						Depr.	Amort.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hawaii									
747-100	\$384	\$ 8	\$423	\$51	\$243	\$226	\$25	\$1109	\$1360
DC-8-62	163	18	271	51	103	96	10	606	712
DC-8-61	163	80	272	51	103	96	10	669	775
DC-8-50	136	147	275	51	86	80	9	695	784
Mainland									
747-100	226	\$ 8	366	51	243	226	25	894	1145
DC-10-10	135	1	324	51	145	135	15	656	806
DC-8-62	96	18	226	51	103	96	10	494	600
DC-8-61	96	80	220	51	103	96	10	550	656
DC-8-50	80	42	209	51	86	80	9	468	557
DC-8-20	80	48	209	51	86	80	9	474	563
727-200	60	38	96	51	65	60	7	310	377
727-100	55	36	90	51	59	55	6	291	352
737-200	39	10	77	51	42	39	4	219	262

\* Block fuel vs segment length data was subjected to a least squares analysis to obtain a simple fuel consumption formula. The intercept point represents the departure fuel, column (3) above, and the variable rate represents a flown hour rate, column (15) next page.

TABLE 2-12 (Cont.)  
TOTAL OPERATING COSTS  
1973 Actual Costs as Allocated

Aircraft Type	Cost per Block Hour			Cost per Flown Hour		
	Flt. Crew Sal. & Exp. **	Inflight Attnd. Sal. & Exp.	Total (11)&(12)	Direct & Burden Maintce.	Flying Fuel & Oil*	Total (14)&(15)
	(11)	(12)	(13)	(14)	(15)	(16)
<u>Hawaii</u>						
747-100	\$337	\$350	\$687	\$427	\$459	\$886
DC-8-62	321	109	430	211	234	445
DC-8-61	386	146	532	218	243	461
DC-8-50	387	109	496	217	138	355
<u>Mainland</u>						
747-100	312	237	549	427	459	886
DC-10-10	284	216	500	419	286	705
DC-8-62	240	90	330	211	234	445
DC-8-61	242	107	349	218	243	461
DC-8-50	237	90	327	217	224	441
DC-8-20	237	90	327	229	271	500
727-200	219	88	307	205	171	376
727-100	220	69	289	205	155	360
737-200	231	65	296	193	129	322

\* See note on previous page.

\*\* This table shows different flight crew cost rates for Hawaii and 48 contiguous states flying whereas table 2-3 has a single composite cost. Table 2-3 is based upon CAB form 41 schedule P-5.2 which consolidates Mainland-Hawaii and 48 state operations.

TABLE 2-12 (Cont.)

TOTAL OPERATING COSTS  
1973 Actual Costs as Allocated

Cost per Revenue Passenger Boarded (17)			Cost per Revenue Dollar (20)				
Passenger Costs			Passenger Freight				
Passenger Handling	\$2.51		Agency Commission	\$.0345	--		
Baggage Handling	.90		Publicity & Advertising	.0202	\$.0078		
Sales & Reservations	2.92						
Misc. Passenger Service	.19		Cost per Departure - Inflight Entertainment (21)				
	\$6.52		(747-100; DC-10-10; DC-8-62; DC-8-61; DC-8-50; DC-8-20)				
Cost per RPM (000) (18)			Movie \$69 Audio \$10				
Passenger Liability Insurance \$.352			Cost per Revenue Passenger Boarded - Meal Service (22)				
Cost per 1000 kg (ton) Cargo Boarded (19)			Block Hrs				
Cargo Service	Mainland	Hawaii	per Trip	1st	Mainland Coach Economy	1st	Hawaii Coach Economy
747-100	\$ 94 (\$ 85)	\$ 89 (\$ 81)	0 - 1/2	1.02	1.02 .37	-	- -
DC-10-10	97 ( 88)	-- --	1/2 - 1	1.61	1.38 .37	-	- -
DC-8-62	130 ( 118)	158 ( 143)	1 - 1 1/2	2.60	2.02 .37	-	- -
DC-8-61	155 ( 141)	157 ( 142)	1 1/2 - 2	3.57	2.74 .37	-	- -
DC-8-50	149 ( 135)	161 ( 146)	2 - 2 1/2	4.46	3.38 .37	-	- -
DC-8-20	149 ( 135)	-- --	2 1/2 - 3	4.56	3.27 .37	-	- -
727-200	151 ( 137)	-- --	3 - 3 1/2	5.17	3.51 .37	-	- -
727-100	148 ( 134)	-- --	3 1/2 - 4	6.00	3.99 .37	-	- -
737-200	173 ( 157)	-- --	4 - 4 1/2	6.53	4.37 .37	-	- -
			4 1/2 - 5	7.34	4.97 .37	5.98	3.95 1.55
			5 - 5 1/2	7.45	5.11 .37	6.47	4.26 1.55
			5 1/2 -	7.53	5.09 .37	6.47	4.55 1.55
Freight Sales							
All Aircraft \$5.35(\$4.85) \$5.35(\$4.85)							
(Hawaii as applicable.)							



TABLE 2-12 (Cont.)  
TOTAL OPERATING COSTS  
1973 Actual Costs as Allocated

	Cost per Aircraft Day (Fixed Expense)						
	Inflight Entertainment	Aircraft Registry Tax	Cash Portion Hull Insurance	Total Cash (23) thru (25)	Hull Insurance Self Reserve	Depreciation & Lease Expense*	Total (26) thru (28)
	(23)	(24)	(25)	(26)	(27)	(28)	(29)
747-100	\$51	\$74	\$173	\$298	\$125	\$5621	\$6044
DC-10-10	38	45	119	202	87	3965	4254
DC-8-62	51	35	14	100	14	1336	1450
DC-8-61	38	32	24	94	25	2090	2209
DC-8-50	38	27	12	77	13	1747	1837
DC-8-20	38	27	5	70	6	1274	1350
727-200	-	17	17	34	17	1257	1308
727-100	-	15	12	27	12	1055	1094
737-200	-	10	11	21	11	635	667

Cost per Dollar of Cash Cost Allocated\* (Less A/C Lease and G&A Expense)

(30)

General & Administrative \$.0572

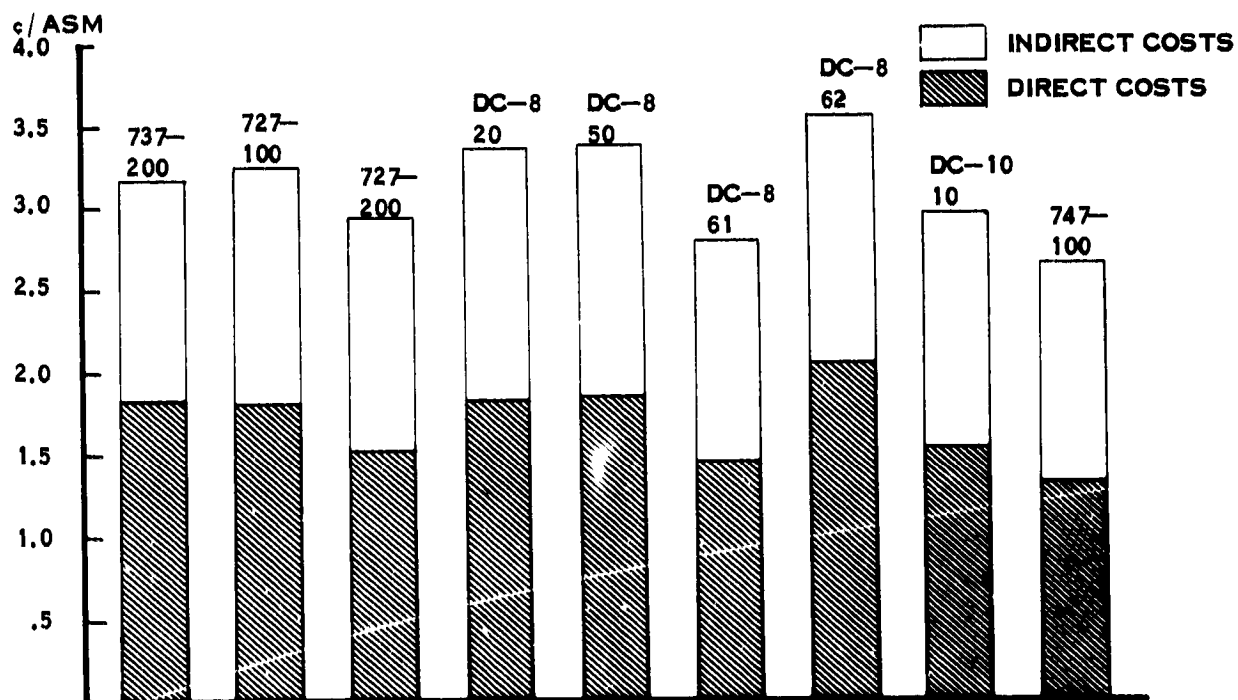
\* For this analysis, all aircraft lease expense was treated as a non-cash expense in allocating general and administrative expenses to flight segments.

TABLE 2-13  
UNITED AIRLINES  
AIRCRAFT MAXIMUM TAKEOFF AND  
LANDING GROSS WEIGHTS

Aircraft Type	Maximum Allowable Takeoff Gross Weight		Maximum Allowable Landing Gross Weight	
	1000 kg	(1000 lbs)	1000 kg	(1000 lbs)
747-100	322.1	(710.0)	255.8	(564.0)
DC-10-10	186.0	(410.0)	152.9	(337.0)
DC-8-62	158.8	(350.0)	108.9	(240.0)
DC-8-61	147.4	(325.0)	108.9	(240.0)
DC-8-51/52	125.2	(276.0)	90.5	(199.5)
DC-8-20	125.2	(276.0)	90.5	(199.5)
727-200	78.0	(172.0)	68.0	(150.0)
727-100*	72.8	(160.6)	62.6	(138.0)
737-200	46.9	(103.5)	44.5	(98.0)

\* Average UA values.

Figure 2-3  
1973 Total Operating Costs - 1000 N.Mi.  
¢/Available-Seat-Nautical-Mile



## YIELD DEVELOPMENT

Figure 2-4 illustrates the yield (revenue per revenue passenger nautical mile) values which are used for this study. Three values have been computed for different applications in the study. All yield data follows the same basic curvilinear pattern by distance, and all reflect actual or projected average revenues. Average revenue over a flight segment, or for an online trip (on United), may vary from the published fare for several reasons. Discounts from the local fares are allowed because of age, various promotional fares, and interline prorates on multi-carrier trips.

### Actual 1973 Segment Yield

Actual segment yield (table 2-14) represents the average revenue over each United flight segment by distance, summarized by 43.4 nautical mile (50 statute mile) blocks. Average passenger trip length within the mileage block is tabulated with the average revenue per passenger mile at the average trip length. Variances in the actual revenue pattern by distance is the result of United's route pattern, and the variety of fares used in different markets.

### 1973 Segment Yield Reflecting Phase 9

The segment yield values reflecting Phase 9 of the Domestic Passenger Fare Investigation (table 2-15) were applied to the 1973 fare levels to reflect United's estimate of the fare decisions on United's revenue generation by segment. Short haul fares were increased and long haul fares were decreased from the relative values in 1973. In addition, many of the discount fares in effect during 1973 were terminated. A new pattern was developed to assist profitability calculation of the test aircraft in future years. The curve is smooth because projections of discount reduction cannot be forecasted for individual United markets.

### 1973 Online Origin and Destination Yield

The online origin and destination (O&D) yield, table 2-16, closely resembles average fares paid by air travelers, even though it includes transportation solely on United Airlines. Actual fares by mileage block are slightly higher than those based on the values shown in table 2-16, because of the dilution from multi-carrier trips. For example, the fare paid by a passenger for a 1058 mile trip between cities A and B on United might be \$90. The yield, 8.5¢ per RPM, would be online O&D yield. Suppose there is another passenger traveling from city A to city C, a trip whose fare is \$100, and there is no single carrier service between A and C. He may then fly United from A to B and change to airline X for the B to C segment. United's share of the \$100, based on interline prorate agreements, may only be \$75. In this case, the revenue would be classified in table 2-16 under the 1058 mile United trip length with a yield of only 7.1¢ per RPM. Actual trip length and yield are for a longer length of haul. All interline traffic is misclassified at the

United trip length; because of the downward sloping yield curve by length of haul, lower yields from longer interline trips are averaged in with true shorter haul yields.

The table 2-16 online O&D yields were developed to assist UTRC's calibration of its passenger demand/flow model for 1973 actual behavior. They were not used in calculating system profitability or ROI's on aircraft modification.

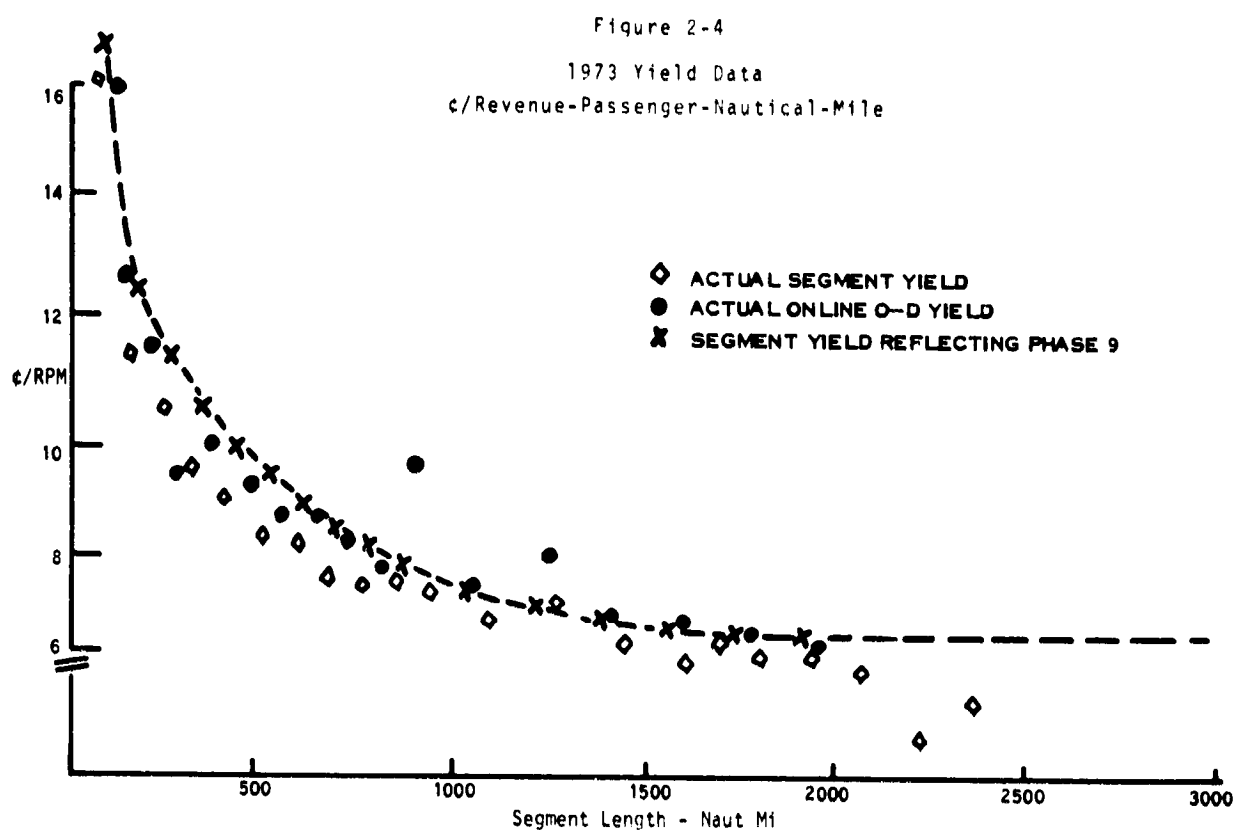


TABLE 2-14  
1973 SEGMENT YIELD  
ACTUAL  
(\$/Revenue Psgr Naut Mile)

<u>Segment Length -</u> <u>Nautical Miles</u>	<u>Yield -</u> <u>\$/RPM</u>	<u>Segment Length -</u> <u>Nautical Miles</u>	<u>Yield -</u> <u>\$/RPM</u>
28	.11864	1154	.06188
70	.16155	1250	.07095
108	.12850	1273	.07084
149	.11385	1312	.06519
191	.10561	1320	.06574
243	.09816	1414	.06636
281	.08913	1452	.06504
319	.09443	1510	.06263
365	.09074	1571	.06453
406	.08896	1600	.06082
462	.08577	1700	.06102
504	.08215	1721	.06427
538	.07951	1780	.06511
591	.08136	1805	.06240
632	.08101	1831	.06426
676	.07584	1877	.06213
716	.07768	1943	.06300
758	.07449	1982	.06788
801	.07379	2016	.05185
835	.07582	2075	.04976
870	.07531	2109	.05917
929	.07407	2142	.06262
975	.07492	2188	.06096
1000	.07160	2227	.04811
1052	.07176	2281	.04767
1085	.06815	2347	.05496

TABLE 2-15

1973 SEGMENT YIELD  
REFLECTING PHASE 9  
(\$/Revenue Psgr Naut Mile)

<u>Segment Length - Nautical Miles</u>	<u>Yield - \$/RPM</u>	<u>Segment Length - Nautical Miles</u>	<u>Yield - \$/RPM</u>
87	.1693	1259	.0693
130	.1434	1303	.0686
174	.1263	1346	.0681
217	.1186	1389	.0676
261	.1130	1433	.0669
304	.1085	1476	.0664
347	.1050	1520	.0662
391	.1013	1563	.0659
434	.0979	1607	.0655
478	.0952	1650	.0653
521	.0927	1693	.0651
564	.0903	1737	.0648
608	.0880	1780	.0648
651	.0861	1824	.0648
695	.0842	1867	.0647
738	.0824	1910	.0647
782	.0810	1954	.0647
825	.0795	1997	.0647
868	.0778	2041	.0647
912	.0766	2084	.0647
955	.0752	2128	.0647
999	.0743	2171	.0647
1042	.0732	2214	.0647
1085	.0722	2258	.0647
1129	.0714	2301	.0647
1172	.0706	2345	.0647
1216	.0699		

TABLE 2-16  
1973 ONLINE ORIGIN AND DESTINATION YIELD  
ACTUAL  
(\$/Revenue Psgr Naut Mile)

<u>Segment Length - Nautical Miles</u>		<u>Yield \$/RPM</u>
113		.16024
152		.12853
209		.11595
284		.09272
368		.09788
465		.09147
552		.08604
638		.08521
722		.08146
815		.07745
888		.09624
1058		.07330
1257		.07939
1421		.06900
1600		.06773
1791		.06565
1949		.06346
2128		.04109
 <u>Hawaiian</u>		
	N.Mi	
HNL-CHI	3702	.04069
HNL-DEN	2937	.04677
HNL-LAX	2199	.04317
HNL-NYC	4341	.04312
HNL-PDX	2564	.04878
HNL-SFO	2084	.04605
HNL-SEA	2683	.042717

## FUEL EFFICIENCY

Block fuel consumption characteristics of the study aircraft are compiled in table 2-17. As described in the previous discussion of fuel costs, trip fuel was ascertained using actual block times for specific city-pairs multiplied by block fuel rates which were determined from surveys covering typical ranges of trip distances.

Table 2-18 tabulates the fuel efficiency of each vehicle at the selected trip distances. Two efficiency measures are provided: ASM's/kg (ASM's/gal) and an energy measure kilo-joules/ASM (BTU's/ASM). The energy efficiency is provided for two different aircraft seating capacities. The columns headed "1973 Seating" are based on actual 1973 seating and accordingly the data is actual 1973 fuel efficiency. The "Increased Density" columns reflect an improved level of fuel efficiency that would have been achieved had a greater number of seats been installed in the aircraft. Aircraft seating is discussed in the paragraphs that follow and fuel efficiency sensitivity to seating density described in greater depth in Section 3.

TABLE 2-17  
BLOCK FUEL CONSUMPTION

Trip Distance - Naut. Miles	Block Fuel - $\frac{\text{KG/APL-MILE}}{\text{(GAL/APL-MILE)}}$								
	737- 200	727- 100	727- 200	DC-8- 20	DC-8- 50	DC-8- 61	DC-8- 62	DC-10- 10	747- 100
200	10.43 (3.38)	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --
300	9.10 (2.95)	12.62 (4.09)	13.98 (4.53)	-- --	-- --	-- --	-- --	-- --	-- --
500	8.16 (2.64)	10.43 (3.38)	11.33 (3.67)	18.82 (6.10)	15.64 (5.07)	18.59 (6.02)	17.96 (5.82)	18.14 (5.88)	31.57 (10.23)
750	7.86 (2.54)	9.52 (3.08)	10.28 (3.33)	-- --	-- --	-- --	-- --	-- --	-- --
1000	7.71 (2.50)	9.07 (2.94)	9.79 (3.17)	15.87 (5.14)	13.19 (4.27)	15.10 (4.89)	13.06 (4.23)	15.10 (4.89)	23.99 (7.77)
1500	-- --	-- --	-- --	15.11 (4.90)	12.54 (4.06)	14.15 (4.58)	-- --	14.66 (4.75)	-- --
1750	-- --	8.73 (2.83)	9.53 (3.09)	-- --	-- --	-- --	-- --	-- --	-- --
2000	-- --	-- --	-- --	14.92 (4.83)	12.36 (4.00)	13.83 (4.48)	11.90 (3.86)	14.78 (4.79)	22.38 (7.25)
2500	-- --	-- --	-- --	14.92 (4.83)	12.37 (4.01)	13.75 (4.45)	-- --	15.01 (4.86)	-- --
3000	-- --	-- --	-- --	-- --	-- --	-- --	12.09 (3.92)	-- --	22.83 (7.40)
4000	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	23.58 (7.64)
4500	-- --	-- --	-- --	-- --	-- --	-- --	12.65 (4.10)	-- --	-- --



TABLE 2-18  
FUEL EFFICIENCY

Airplane	Trip Distance - Naut. Miles	ASM's/KG (ASM's/GAL)		KILLO-JOULES/ASM (BTU's/ASM)	
		1973 Seating	Increased Density	1973 Seating	Increased Density
727-100 (Incl. QC Psgr.)	300	7.65 (23.62)	8.07 (24.91)	5649 (5354)	5355 (5076)
	500	9.26 (28.58)	9.77 (30.15)	4668 (4424)	4425 (4194)
	750	10.15 (31.30)	10.70 (33.02)	4262 (4040)	4040 (3829)
	1000	10.65 (32.87)	11.24 (34.67)	4059 (3847)	3848 (3647)
	1750	11.06 (34.14)	11.67 (36.01)	3908 (3704)	3705 (3512)
727-200	300	8.77 (27.06)	9.43 (29.11)	4930 (4672)	4584 (4345)
	500	10.82 (33.38)	11.63 (35.90)	3997 (3788)	3717 (3523)
	750	11.93 (36.82)	12.83 (39.59)	3624 (3435)	3370 (3194)
	1000	12.52 (38.64)	13.47 (41.55)	3454 (3273)	3211 (3044)
	1750	12.86 (39.69)	13.83 (42.68)	3362 (3187)	3126 (2963)
737-200	200	8.87 (27.37)	9.29 (28.67)	4874 (4620)	4653 (4410)
	300	10.16 (31.35)	10.64 (32.84)	4256 (4034)	4063 (3851)
	500	11.34 (34.98)	11.88 (36.64)	3815 (3616)	3642 (3452)
	750	11.77 (36.32)	12.33 (38.05)	3673 (3482)	3507 (3324)
	1000	12.00 (37.04)	12.57 (38.79)	3603 (3415)	3439 (3260)
747-100	500	9.99 (30.83)	12.22 (37.71)	4328 (4102)	3538 (3354)
	1000	13.15 (40.56)	16.08 (49.61)	3289 (3118)	2689 (2549)
	2000	14.09 (43.48)	17.24 (53.18)	3069 (2909)	2509 (2378)
	3000	13.82 (42.63)	16.90 (52.14)	3130 (2966)	2559 (2425)
	4000	13.37 (41.26)	16.36 (50.47)	3234 (3065)	2644 (2506)
DC-8-20	500	6.40 (19.75)	7.38 (22.77)	6756 (6403)	5859 (5553)
	1000	7.59 (23.42)	8.75 (27.00)	5698 (5400)	4942 (4684)
	1500	7.97 (24.59)	9.19 (28.35)	5426 (5143)	4706 (4461)
	2000	8.07 (24.91)	9.31 (28.72)	5356 (5076)	4645 (4403)
	2500	8.07 (24.91)	9.31 (28.72)	5356 (5076)	4645 (4403)
DC-8-51/-52	500	7.82 (24.13)	8.88 (27.39)	5529 (5240)	4871 (4616)
	1000	9.27 (28.61)	10.53 (32.48)	4663 (4420)	4108 (3894)
	1500	9.75 (30.09)	11.07 (34.16)	4434 (4202)	3906 (3702)
	2000	9.90 (30.55)	11.24 (34.68)	4367 (4139)	3847 (3646)
	2500	9.89 (30.52)	11.23 (34.64)	4372 (4143)	3851 (3650)
DC-8-61	500	8.89 (27.42)	10.64 (32.83)	4866 (4612)	4064 (3851)
	1000	10.94 (33.76)	13.10 (40.43)	3952 (3746)	3300 (3128)
	1500	11.68 (36.03)	13.99 (43.15)	3703 (3509)	3092 (2931)
	2000	11.95 (36.86)	14.31 (44.14)	3620 (3431)	3023 (2865)
	2500	12.02 (37.08)	14.39 (44.40)	3598 (3410)	3005 (2848)
DC-8-62	500	7.10 (21.92)	8.29 (25.58)	6086 (5768)	5216 (4943)
	1000	9.77 (30.14)	11.40 (35.18)	4426 (4195)	3793 (3595)
	2000	10.72 (33.07)	12.51 (38.59)	4034 (3824)	3457 (3277)
	3000	10.55 (32.56)	12.31 (37.99)	4098 (3864)	3512 (3329)
	4500	10.09 (31.13)	11.77 (36.33)	4286 (4062)	3673 (3481)
DC-10-10	500	12.86 (39.68)	14.22 (43.86)	3362 (3187)	3042 (2884)
	1000	15.45 (47.67)	17.08 (52.68)	2799 (2653)	2533 (2401)
	1500	15.91 (49.10)	17.59 (54.26)	2718 (2576)	2459 (2331)
	2000	15.78 (48.69)	17.44 (53.81)	2740 (2597)	2480 (2350)
	2500	15.54 (47.96)	17.18 (53.00)	2732 (2637)	2518 (2386)

## AIRCRAFT SEATING

The seat quantity data utilized in the fuel efficiency computations are compiled in columns (1) and (5) of table 2-19. Columns (2), (3), and (4) have been added to show changes in seating since the 1973 baseline year. The 1973, 1974, and 1975 actuals are averages computed by dividing total available seat miles by total airplane miles. The actuals are not unitary because of interior configuration changes made during each year. The column (5) data is the estimated seating density that could be attained by reducing the first class (F)/coach (Y) seat ratio and by reducing coach seat pitch.

TABLE 2-19  
AIRCRAFT SEATING

Airplane	Actual Average Seats per Revenue Departure			(4) March 1976 In-Service Seating Configurations (2 Class)	(5) Estimated Seating w/Increased Density**
	(1) 1973	(2) 1974	(3) 1975		
737-200	92.6	95.0	95.0	10F/ 85Y = 95	12F/ 85Y = 97
727-100	96.7	96.3	96.0	12F/ 86Y = 98	12F/ 90Y = 102
727-200	122.8	124.0	125.0	14F/112Y = 126	14F/118Y = 132
DC-8-20	120.5	126.3	127.0	22F/107Y = 129	14F/125Y = 139
DC-8-51/-52	122.5	131.4	127.0	22F/107Y = 129	14F/125Y = 139
DC-8-62	127.7	133.9	142.5	20F/123Y = 143	16F/133Y = 149
DC-8-61	165.4	183.5	184.0	28F/156Y = 184	28F/170Y = 198
DC-10-10	233.5	238.0	238.8	42F/200Y = 242	46F/212Y = 258
747-100	315.6	318.5	339.0	*38F/312Y = 350	38F/348Y = 386

\* Includes 8 seats in upper deck lounge not usually sold but which are salable.

\*\* Increased density objectives: (1) 10%/90% F/Y split, (2) 0.965 m (38 in)/0.864 m (34 in) F/Y seat pitch.

The F/Y seat split guideline for increased density estimates is 10% first class/90% coach. The seat pitch guidelines are .965 m (38 in) in first class and .864 m (34 in) in coach. The paragraphs that follow discuss each fleet type and some of the opportunities for increasing the seating density. The past year has seen some increase in density implemented via seat mix change that is attributable to CAB imposed widening first class/coach class fare differentials.

737-200.-- This airplane now operates in essentially the increased density configuration. Coach class seat pitch is .864 m (34 in) and F/Y split is 10%/90%. The 1973 actual average seat quantity (92.6) reflects a 25%/75% F/Y ratio in service for part of the year while the seat mix changeover was in process. The seat quantity difference between the March 1976 in-service configuration and increased density estimate is due to a garment bag stowage module currently installed to handle passenger carry-on items. The demand for this carry-on stowage space is strong. Seat pitch in first class is .914 m (36 in). A .965 m (38 in) pitch would eliminate a row of seats and is not considered an essential requirement due to the short haul nature of the airplane.

727-100.-- The 727-100 is somewhat inflexible from the standpoint of interior configurations. The short distance between the mid-cabin galley and the aft pressure bulkhead essentially precludes adding seats by reducing seat pitch to .864 m (34 in) from the existing .914 m (36 in). The current configuration has 98 seats with a 12%F/88%Y mix. The 102 seats shown in column (5) of table 2-19 exclude the garment bag stowage module now installed.

727-200.-- As in the case of the 737, the 727-200 has always operated with a .864 m (34 in) seat pitch in coach. The 1973 actual average 122.8 seat total reflects a 23%/77% F/Y mix. Current operations have an 11%/89% mix with 126 seats and a garment bag module installed. If the garment bag module were removed, an 11%/89% mix produces the 132 seats as shown in table 2-19. The removal of these stowage modules would force travelers to revert back to folding their suits and packing for cargo compartment carriage. Also, it would inconvenience many passengers who now are able to avoid checking baggage via use of a small carry-on suitcase plus a garment bag. Due to the customer convenience aspects of these modules, it perhaps is unlikely that any carrier would remove them on a unilateral basis.

Before discussing the DC-8 airplanes individually, it is important to note that the 1973 actual averages were biased downward by the installation of 5-across seating. The 5-across configurations have now been replaced by "two-by-two" seating which consists of two triple seat assemblies (6-across) with fold down center seats.

DC-8-20/-51/-52.-- The 1973 and current configurations feature .965 m (38 in) seat pitch in coach as well as first class. It is estimated that by reducing coach class seat pitch to .864 m (34 in) and changing the mix to 10%/90% the seat total can be increased to 139. The current 129 seats are based on a 17%/83% F/Y mix. Table 2-19 shows more average seats for the DC-8-51/-52 per 1974 departure than indicated in the current 2-class configuration column. This is because the 1974 average includes a number of aircraft dedicated to charter operations with 149 seat all-coach interiors.

DC-8-61.-- The DC-8-61 has a galley and lavatory complex just forward of the wing. The area forward of this complex is the first class cabin and contains 28 seats. Splitting this section in an attempt to attain a 10%/90% split does not increase capacity as the seats gained by 6-across coach assemblies are essentially offset by a seat row lost due to the addition of a class divider. In the tourist cabin there are currently 156 seats with a mixture of .914 m (36 in) and .940 m (37 in) seat pitch. By reducing seat pitch to .864 m (34 in) coach seating can be increased to 170 for a total of 198 with a resulting mix of 14%F/86%Y. United's DC-8-61's have six emergency exits aft of the wing whereas most others have no more than four. United's seating, as a consequence, compared to others with the same seat pitch standard, may be slightly lower due to the loss of seats adjacent these additional exits.

DC-8-62.-- The DC-8-62 with 5-across seating had 122 seats. Current capacity is 143 with a 14%/86% mix and .965 m (38 in)/.914 m (36 in) spacing. The relative location of exits in the tourist cabin essentially precludes .864 m (34 in) spacing. However, a .889 m (35 in) seat pitch in coach combined with a 10%/90% mix could yield a 149 passenger capacity.

The average number of DC-8-62 seats per departure during 1973 was 127.7 as indicated by column (1) of table 2-19. Comparing with the 122.5 DC-8-51/-52 average, one can readily see why the DC-8-62 c/seat-mile depreciation element was so high as discussed previously.

DC-10 and 747 aircraft now operate with 8-across and 9-across coach seating, respectively, both with .914 m (36 in) spacing. The increased density estimates in column (5) of table 2-19 assume .864 m (34 in) spacing. However, it is noted that the CAB has designated 9-across and 10-across future standards for these aircraft for fare setting purposes. The closer seat pitch has not herein been combined with 9- and 10-across standards as we feel that for the long haul markets these airplanes serve there may be strong consumer resistance to combined seat pitch reduction and seat width reduction. Some additional comments concerning these aircraft include:

DC-10-10.-- This airplane has a lower lobe galley. The galley lift and primary main deck galley service area is located on the No. 2 door cross-aisle. This becomes a logical class divider with first class service moving forward to the cabin area between the No. 1 and No. 2 doors. This is a large first

class cabin: 38 seats plus salable 4-place lounge. If the lounge were replaced by standard seats and the existing carry-on luggage stowage module deleted, the first class seating in this cabin could be increased to 46.

With respect to tourist seating, the 1973 average shown in table 2-19 reflects in part a lounge which occupied a sizeable area in the forward portion of the coach cabin and was in the process of phase-out. The coach lounges were completely removed by the end of calendar year 1973. The March 1976 in-service configuration is 42F/200Y or 242 seats total. The reduction of coach seat pitch to .864 m (34 in) would add one row of eight seats in the mid-cabin area. The 212 coach seats shown in table 2-19, column 5, include this added row plus an additional four seats aft of the galley service center in an area now reserved for passenger cross-traffic.

A 46F/212Y interior is an 18%/82% F/Y mix. To achieve the 10%/90% objective would require installation of a class divider in the middle of the existing first class section. This has not been included in this study even though total seats could be increased. The reason is a coach lavatory problem. All coach lavatories are located at the aft end of the airplane and access difficulty from the forward coach area has been the subject of numerous customer complaints. Expanding the coach compartment in the forward direction to achieve a 10%/90% mix would compound the lavatory problem.

747-100.-- The 747 actual average seats per departure for 1973 and 1974 reflect coach lounge installations (table 2-19, columns 1 and 2). The 38F/312Y arrangement (column 4) is an 11%/89% F/Y split. The first class cabin is the area forward of the No. 1 door and a 10%/90% seat mix objective can be met entirely by increasing the density of the coach section. Reducing coach seat pitch to .864 m (34 in) can increase tourist class seating to approximately 348. The resultant total of 386 seats has a 10%F/90%Y mix. It should perhaps be noted that United's 747's have lower lobe galleys and therefore, for comparable seating standards, may have a greater number of seats than other airlines (excluding American which also has underfloor galleys).

If increased seating density were to be achieved by 10-across coach seating (or 9-across for the DC-10) in lieu of seat pitch change, a few more seats might be gained. While either alternative could have been used in the fuel efficiency analysis of this study, the seat pitch change was selected as it conforms to the contract work statement.

#### AIRFRAME/ENGINE TIME EXTENSION

Table 2-20 presents several factors relevant to the useful life of United's existing jet fleets. In general, it is not likely that an airplane will be phased out because it encounters a structural life limit. Aircraft retirements are more apt to result from other factors such as:

- Over capacity or mis-matched fleet capacity mix

- Fleet simplification
- Poor fuel efficiency
- Environmental pressures (such as noise that cannot be reduced to acceptable levels at a reasonable cost).

As shown in table 2-20, only the 737, 747 and DC-10 are subject to airframe structural life limits. These limits, themselves, can probably be extended by additional testing and, when flight cycles approach the limits, such testing will be sponsored if it is a less costly alternative than gear replacement. There are some life limited parts in turbine engines which are monitored and replaced at convenient maintenance opportunities. The engine parts monitoring and replacement programs are considered relatively small cost elements.

The rightmost two columns of table 2-20 show the potential cost impact of noise retrofit regulation. Not only will the costs be high, but some of the fleets may be subjected to operational restrictions such as a reduced maximum allowable takeoff weight and/or less than maximum flaps on landing. It is perhaps ironic that the most inefficient airplane (DC-8-20) from a fuel consumption standpoint is the airplane predicted to require the least costly noise retrofit kit.

TABLE 2-20  
EXISTING AIRCRAFT USEFUL LIFE EXTENSION

Fleet	Total Time on High-Time Aircraft as of 12-31-74		Life Limited Structure	Life Limit	Estimated Cost per A/C to Extend Structural Life (1973 \$)	Estimated Noise Retrofit Costs per A/C (1973 \$) to Meet	
	Flight Hours	Flight Cycles				FAR 36 w/Trades	FAR 36 w/o Trades
DC-8-20	49,703 hrs	17,646 cycles	None	--	--	\$ 84,000 (2)	\$ 84,000 (2)
DC-8-51/-52	48,946	19,480	None	--	--	530,000 (2)	1,030,000 (2)
727-100	27,934	22,526	None	--	--	90,000	185,000
DC-8-61	25,368	6,623	None	--	--	530,000	1,030,000
DC-8-62	19,482	5,363	None	--	--	500,000	710,000
727-200	15,088	12,624	None	--	--	90,000	185,000 (2)
747-100	14,800	4,339	Nose gear	50,000 cycles	\$210,000 (1)	300,000	300,000
737-200	11,637	15,631	Nose & main gear	75,000 cycles	130,000 (1)	200,000	200,000 (2)
DC-10-10	9,557	4,938	Nose & main gear	50,000 cycles	750,000 (1)	-0-	-0-

- NOTES: (1) Gear replacement costs only; does not include revenue losses, if any, due to aircraft downtime.  
(2) Operational restrictions required in addition to retrofit; costs associated with operational restrictions, if any, are not included in estimates shown.

## AIRCRAFT PURCHASE COSTS

Aircraft purchase cost estimates are shown in table 2-21. For aircraft out of production, the fair market value of the airplane in the used aircraft market is estimated. The spare parts cost relationships are based on actual data compiled by United's Purchasing Division and include spare engines as well as engine and airframe spare parts and assemblies.

The aircraft costs are based, where available, upon actual invoice data. A price range is shown because delivery prices will vary due to differences in order date and/or delivery date. The order date is a factor when basic price changes are implemented at regular or irregular intervals by the manufacturer. The delivery date is a factor because of the nature of the escalation clauses contained in purchase agreements. A cost range is shown for used aircraft because prices vary depending upon the amount of time remaining before the next overhaul is due and upon the amount of modification work performed by the seller for the buyer.

TABLE 2-21  
AIRCRAFT COST ESTIMATES  
(1973 \$ - MILLIONS)

<u>Current Production Aircraft</u>	<u>Airplane Cost (w/o Spares)</u>
737-200	5 to 5½
727-200	7½ to 8
DC-10-10	17½ to 18
747	25 to 26
<u>Out-of-Production Aircraft</u>	
DC-8-20	½ to ¾
DC-8-61	5 to 5½
DC-8-62	8 to 8½
DC-8-50	1½ to 2
<u>Spare Relationships</u>	
<u>Aircraft</u>	<u>Spare Cost/Apl as % of Airplane Unit Cost</u>
727/737	9.6%
DC-8	11.1
DC-10	13.4
747	14.1

### SECTION 3

#### FUEL CONSERVING OPERATIONAL PROCEDURES

##### FLIGHT OPERATIONS SENSITIVITY

The operating procedures sensitivity study explored the effect on fuel usage of varying certain specific parameters. The parameters selected were those over which the airplane operator has primary control, i.e., speed, altitude, etc. The effect of these parameters has been studied by the airline in the past, but usually on the basis of the difference between the current operating point and a specific proposed operating point.

##### Data and Computation

This study made use of the data base for United's computerized flight planning function. This is "live" data, used daily to generate flight plans for actual operations. Actual historical fuel used data was not used here as it was in the operating cost analysis for the simple reason that it was not available in a form which would allow identification of the effect of the separate parameters of this study.

Airplane performance data used in computer flight planning consists of the following:

- Time, fuel, and distance to climb to any altitude as a function of takeoff weight and temperature, including allowances for takeoff and maneuvering. Only a single climb schedule is used. It is predicated on use of an engine thrust rating, i.e., Maximum Climb Thrust, and a constant indicated airspeed to some altitude followed by climb at constant Mach number.
- Maximum initial cruise weights for various altitudes as a function of temperature for the appropriate engine thrust rating. This information is used to determine altitude capability both in tially and for step climb considerations.
- Cruise specific range data as a function of weight and altitude over the cruise speed range.
- Time, fuel, and distance to descend from any altitude including a standard allowance for approach and landing. Only a single descent schedule is used and approach allowances are not tailored for specific destinations.
- Holding fuel consumption data which allows planned total fuel load to be adjusted to account for anticipated delays.



These data are processed with curve fitting routines and are stored in the flight planning computer in the form of mathematical coefficients.

The initial source of airplane performance data is the airplane manufacturer. That data is checked on performance guarantee flights, new airplane acceptance flights and during an initial service period evaluation and is adjusted as necessary. A small amount of cruise data is recorded on each flight of each airplane in service and a periodic performance audit is conducted on each airplane and each fleet. The results of these audits are used to (1) identify mechanical problems on individual airplanes, i.e., engine deterioration, high drag, faulty airspeed systems, excessive pneumatic bleed air losses, etc., and initiate corrective action, and (2) form the basis for adjustment of the flight planning performance data to reflect that specific fleet of airplanes. Climb and descent data are checked only if flight crew comments indicate it is needed. Basic airplane data and flight planning computer input data are modified as dictated by experience.

In addition to the programs which produce optimum flight plans as described above, several options are available for special cases. These include 5th-pod flight planning for the 747, planning at a specific altitude and/or Mach, planning at optimum altitude at a specific Mach, blocking altitudes and routes from consideration because of military maneuvers or severe weather, etc.

UAL automatic flight planning is accomplished by a Sperry Rand Univac 1108 computer. Flight plans are computed for all flight segments 350 nautical miles or more in length. Actual weights, rather than standard weights, are used in computing each plan. These weights include:

1. Empty weight of the specific aircraft assigned to the flight.
2. The payload planned for the specific flight.
3. The computed amount of reserve fuel required to qualify the alternate airport designated by the dispatcher for the specific flight.
4. The amount of holding or detouring fuel, if any, specified by the dispatcher for the specific flight.

Use of actual weights optimizes this aspect of a flight plan. The amount of fuel required to safely complete each flight is all that is carried.

A route comparison program is used for all long-range flights (longer than 1000 nautical miles). The computer analyzes the forecast high-level wind patterns and selects the least-time track. Altitude and speed (Mach) are optimized in all flight plans regardless of stage length. In selecting the optimum altitude(s), the program checks all possible flight profiles at all operable flight levels, employing step-climb and step-descent when wind and temperature conditions along the route indicate that an advantage will be gained.

Mach number is optimized after the program compares computed flight time at standard Mach to schedule flight time. Standard Mach is a pre-selected speed that approximates long-range-cruise speed at heavy weights and was formerly used as the basis for a constant-Mach-cruise program. If the computed time is equal to or longer than scheduled time, a standard Mach plan is produced. If the computed time is less than scheduled, the program will recompute at successively lower Mach numbers until scheduled time or long-range-cruise Mach is reached. All flights for which a schedule is not published, specifically charters and ferries, are planned at long-range-cruise Mach to conserve fuel.

The accuracy of a flight plan is, of course, dependent on the accuracy of the weather, weight and performance data used, the calculation methods, the assumptions made and the techniques used to actually conduct the flight. Any attempt to assign accuracy values to each of the foregoing variables and combine them to get a final measure would result in a detailed statistical analysis. Instead, weather and performance data accuracy have been touched on in their respective discussions; calculation methods are those generally accepted in the industry and are of known accuracy; assumptions, particularly those related to departure and arrival fuel and time allowances, are under continual reevaluation; and, in general, United's more than 5,000 flight crew members pay close attention to the computer generated flight plans.

A recent one year period shows that monthly averages of actual fuel used exceeded planned fuel by 23 to 90 kg (50 to 200 pounds) per flight. This is based on a system having about 1500 flights per day varying in length from less than 100 to more than 4000 nautical miles in equipment ranging from early generation DC-8's to 737's to 747's. It is recognized that average values tend to mask occasional large variations. Under unfavorable conditions such as unanticipated high enroute temperature or headwinds or adverse ATC descent and approach routing, it is possible to use 5 percent more fuel than planned on a particular flight. However, the high degree of confidence flight crews place in the computer generated flight plans indicates such large variations from plan to be the exception rather than the rule.

### Study Baseline

The baseline for the sensitivity study was selected to be generally representative of airline operation. The values selected for each parameter are tabulated in table 3-1 and discussed in the paragraphs that follow.

Final Cruise Altitude. -- The analysis was based on use of step climb in cruise where necessary. The cruise altitude specified is the final cruise altitude. The actual altitude selected for all fleets except the 737-200 was 10,668 m (35,000 feet). The optimum altitude in terms of fuel consumption is dependent on weight, but for most of the fleets does go above the selected altitudes shown in table 3-1. Although the airline attempts to plan and fly their trips near the optimum altitude, operational considerations, such as adverse winds, do not always allow this. In the case of the 737 fleet, the altitudes selected were considerably lower because of the short segment lengths flown.

TABLE 3-1  
SENSITIVITY STUDY  
BASELINE

Airplane Type	Final Cruise Altitude	Cruise Mach No.	Landing Weight*	Climb Schedule	Descent Schedule
737-200	8,839 m (29,000 FT)	.73	36,644 KG (80,800 LB)	320 IAS/.73 M	.73 M/320 IAS
727-100	10,668 m (35,000 FT)	.80	50,658 KG (111,700 LB)	340 IAS/.78 M	.80 M/340 IAS
727-200	10,668 m (35,000 FT)	.80	56,372 KG (124,300 LB)	340 IAS/.78 M	.80 M/340 IAS
DC-8-20	10,668 m (35,000 FT)	.80	75,011 KG (165,400 LB)	300 IAS/.78 M	.80 M/330 IAS
DC-8-50	10,668 m (35,000 FT)	.80	77,098 KG (170,000 LB)	300 IAS/.78 M	.80 M/330 IAS
DC-8-61	10,668 m (35,000 FT)	.80	88,707 KG (195,600 LB)	300 IAS/.78 M	.80 M/330 IAS
DC-8-62	10,668 m (35,000 FT)	.80	82,313 KG (181,500 LB)	300 IAS/.78 M	.80 M/330 IAS
DC-10-10	10,668 m (35,000 FT)	.83	128,844 KG (284,100 LB)	300 IAS/.82 M	.83 M/340 IAS
747-100	10,668 m (35,000 FT)	.84	194,784 KG (429,500 LB)	340 IAS/.82 M	.86 M/340 IAS

\* Based on average 1973 payload obtained from CAB Form 41, Sched. T-2(b).

Landing Weight. -- Landing weight was the parameter selected to represent airplane weight. It is essentially independent of trip length except, of course, for specific market influences. The landing weight is composed of operating weight empty, reserve fuel and payload. Current values of operating weight empty were used. Reserve fuel was set at approximately 150% of the minimum FAR required reserve fuel for domestic operations. Within United, this reserve value is identified as minimum FAR reserve fuel plus UAL contingency fuel which by definition is 50% of the FAR reserve. The baseline payload was set at the average 1973 payload for the fleet type as obtained from CAB form 41 data.

The sensitivity analysis investigated the effects of landing weight variation. The results may be applied to any of the components of the landing weight; i.e., changing reserve fuel by a certain weight increment would have the same effect on fuel consumption as would changing payload or empty weight by the same weight increment.

Cruise Mach Number. -- The cruise Mach number selected was United's standard Mach for each fleet. This speed is a constant Mach number which is approximately the long-range-cruise speed for heavy weights. During the 1973 base year, the great majority of all flights was planned at these speeds. Periodic routine checks of flight data are made to determine average Mach number flown. In recent years, the results of these periodic surveys show a high degree of compliance on the part of flight crews to fly the airplanes at the standard Mach numbers. The 737-200 fleet, due to its short segment lengths, is not included in the ongoing flight data monitoring program. However, the standard Mach number is considered the best choice for a baseline.

### Analysis

The results of the flight fuel and time study using the baseline parameters as a function of trip distance are shown in table 3-2. It should be remembered that these data represent direct flight fuel and time and do not include taxi, delays, wind and temperature variations, unusual routings or miscellaneous fuel usage such as running of the APU. (Section 2 fuel data includes all of these factors except for APU fuel consumption.)

The effects of varying altitude, weight and Mach number are shown in tabular form in tables 3-3 through 3-11.

Altitude Variation.-- Altitude has a very powerful influence on fuel consumption. The amount varies from fleet to fleet, but the trend is common. There is also some variation with segment length; however, for the typical range of segment lengths in domestic airline operation, it is not considered to be significant. The 737 (table 3-3) is shown essentially at its optimum altitude. The 727 models (tables 3-4 and 3-5) show slight gains (about 1%) by increasing altitude 1219 m (4000 ft). The 747, DC-10 and DC-8's (tables 3-6 through 3-11), except the DC-8-61, show that increasing altitude 1219 m (4000 ft) will decrease fuel consumption 3 to 5%. It should be remembered that the baseline altitude was selected to be representative of the total

TABLE 3-7  
BASELINE FLIGHT FUEL/TIME

Trip Distance Naut. Miles	BASELINE TRIP FLIGHT FUEL - 1000 KG (1000 LB)/FLIGHT TIME - HOURS:MINUTES								
	737	727 Std & QC	727-200	DC-8-20	DC-8-50	DC-8-61	DC-8-62	DC-10	747
200	1.6 ( 3.6) :36	---	---	---	---	---	---	---	---
300	2.2 ( 4.8) :49	3.1 ( 6.9) :46	3.4 ( 7.5) :46	---	---	---	---	---	---
500	3.3 ( 7.2) 1:17	4.5 (10.0) 1:12	4.9 (10.8) 1:12	8.2 (18.0) 1:14	6.7 (14.8) 1:14	7.3 (16.2) 1:14	6.4 (14.2) 1:14	8.3 (18.3) 1:14	13.0 ( 28.7) 1:13
750	4.6 (10.2) 1:52	6.3 (13.9) 1:44	6.8 (15.1) 1:44	---	---	---	---	---	---
1000	6.0 (13.3) 2:27	8.1 (17.9) 2:17	8.8 (19.4) 2:17	14.5 (32.0) 2:19	12.0 (26.4) 2:19	13.0 (28.7) 2:19	11.4 (25.2) 2:19	14.8 (32.7) 2:17	22.6 ( 49.8) 2:15
1500	---	---	---	21.1 (46.5) 3:24	17.4 (38.3) 3:24	18.9 (41.7) 3:24	---	21.6 (47.6) 3:20	---
1750	---	13.8 (30.5) 3:55	15.0 (33.0) 3:55	---	---	---	---	---	---
2000	---	---	---	28.0 (61.7) 4:29	22.9 (50.6) 4:29	25.1 (55.3) 4:29	21.8 (48.0) 4:29	28.5 (62.9) 4:23	42.5 ( 93.7) 4:19
2500	---	---	---	35.3 (77.8) 5:34	28.8 (63.5) 5:34	31.6 (69.6) 5:34	---	35.6 (78.6) 5:26	---
3000	---	---	---	---	---	---	32.8 (72.3) 6:38	---	63.6 (140.2) 6:23
4000	---	---	---	---	---	---	---	---	86.1 (189.8) 8:28
4500	---	---	---	---	---	---	51.1 (112.6) 9:53	---	---

fleet operation. It is apparent from the tables that the baseline altitudes are generally somewhat below the optimum altitude. The tables also show very substantial fuel consumption increases as altitude is decreased 1219 m (4000 ft) below the baseline.

The effect of altitude variation on flight time was also investigated and found to be insignificant in view of the fuel burnout considerations.

Weight Variation.-- The landing weight variation was found to be generally independent of segment length on the basis of % burnout. There are some exceptions: (1) the derivative airplane which incorporates a fuselage stretch such as the 727-200 and the DC-8-61 (tables 3-5 and 3-8) shows a definite change in % burnout with segment length; and (2) the long range airplanes, 747 and DC-8-62 (tables 3-11 and 3-9), show a change in % burnout only on the longest segment chosen.

If weight variation is considered as a percentage of landing weight, it again is apparent that stretched airplanes are more sensitive to weight increase. In general, a 5% increase in landing weight would result in a 2.5 to 3.0 increase in trip fuel consumption. The 727-200 and DC-8-61 fuel consumption is about 0.6% greater than their short body counterparts.

TABLE 3-3

## OPERATIONS SENSITIVITY 737-200

BASELINE: MACH NO: .73

ALTITUDE: 3839 m (25 000 FT)

PAYLOAD: 5261 KG (11 600 LB)

## ALTITUDE VARIATION

TRIP DISTANCE N.M.I.	+1828 m (6000 FT)				+1219 m (+4000 FT)				-1219 m (-4000 FT)			
	Δ FUEL		Δ TIME MIN		Δ FUEL		Δ TIME MIN		Δ FUEL		Δ TIME MIN	
	KG (LB)				KG (LB)				KG (LB)			
200	0 (0)	0	0		0 (0)	0	-1		45 (100)	2.8	-1	
300	45 (100)	2.1	0		45 (100)	2.1	-1		45 (100)	2.1	0	
500	-45 (-100)	-1.4	1		-91 (-200)	-2.8	0		181 (400)	5.6	0	
750	-181 (-400)	-3.9	1		-181 (-400)	-3.9	0		317 (700)	6.9	-1	
1000	-317 (-700)	-5.3	2		-272 (-600)	-4.5	0		454 (1000)	7.5	-2	

## WEIGHT VARIATION

TRIP DISTANCE N.M.I.	+4535 KG (10 000 LB)				+2268 KG (5000 LB)				-2268 KG (-5000 LB)			
	Δ FUEL		Δ TIME MIN		Δ FUEL		Δ TIME MIN		Δ FUEL		Δ TIME MIN	
	KG (LB)				KG (LB)				KG (LB)			
200	136 (300)	8.3	-		45 (100)	2.8	-		-45 (-100)	-2.8	-	
300	136 (300)	6.3	-		91 (200)	4.2	-		-45 (-100)	-2.1	-	
500	227 (500)	6.9	-		91 (200)	2.8	-		-91 (-200)	-2.8	-	
750	272 (600)	5.9	-		136 (300)	2.9	-		-136 (-300)	-2.9	-	
1000	363 (800)	6.0	-		181 (400)	3.0	-		-181 (-400)	-3.0	-	

## MACH NUMBER VARIATION

TRIP DISTANCE N.M.I.	+.02				-.02			
	Δ FUEL		Δ TIME MIN		Δ FUEL		Δ TIME MIN	
	KG (LB)				KG (LB)			
200	45 (100)	2.8	0		0 (0)	0	0	
300	45 (100)	2.1	0		0 (0)	0	1	
500	91 (200)	2.8	-1		-45 (-100)	-1.4	1	
750	136 (300)	2.9	-2		-91 (-200)	-2.0	2	
1000	181 (400)	3.0	-3		-136 (-300)	-2.3	3	

TABLE 3-4  
OPERATIONS SENSITIVITY 727-100

BASELINE: MACH NO: .80 ALTITUDE: 10 668 m (35 000 FT)  
PAYLOAD: 5850 KG (12 900 LB)

ALTITUDE VARIATION

	+1219 m (+4000 FT)			-1219 m (-4000 FT)			-2438 m (-8000 FT)					
TRIP DISTANCE N.M.I.	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN			
	KG (LB)			KG (LB)			KG (LB)					
300	0	( 0)	0	91	( 200)	2.9	-1	181	( 400)	5.8	-1	
500	-45	(-100)	-1.0	0	181	( 400)	4.0	-1	454	(1000)	10.0	-2
700	-91	(-200)	-1.4	1	363	( 800)	5.8	-1	816	(1800)	13.0	-2
1000	-136	(-300)	-1.7	1	499	(1100)	6.2	-2	1134	(2500)	14.0	-4
1750	-181	(-400)	-1.3	1	816	(1800)	5.9	-4	2086	(4600)	15.1	-7

WEIGHT VARIATION

TRIP DISTANCE N.M.I.	+4535 (+10 000 LB)				-4535 KG (-10 000 LB)		
	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN	
	KG (LB)			KG (LB)			
300	181	( 400)	5.8	-	-136 ( -300)	-4.4	-
500	227	( 500)	5.0	-	-227 ( -500)	-5.0	-
750	363	( 800)	5.8	-	-272 ( -600)	-4.3	-
1000	454	(1000)	5.6	-	-408 ( -900)	-5.0	-
1750	862	(1900)	6.2	-	-726 (-1600)	-5.3	-

MACH NUMBER VARIATION

TRIP DISTANCE N.M.I.	+.02				-.02			
	Δ FUEL		TIME MIN	Δ FUEL		TIME MIN		
	KG	(LB)		KG	(LB)			
300	45	(100)	1.5	-1	0	( 0)	0	0
500	45	(100)	1.0	-1	0	( 0)	0	1
750	91	(200)	1.4	-1	-45	(-100)	-0.7	2
1000	136	(300)	1.7	-3	-45	(-100)	-0.6	2
1750	272	(600)	2.0	-5	-136	(-300)	-1.0	4

TABLE 3-5  
OPERATIONS SENSITIVITY 727-200

BASELINE: MACH NO: .80

ALTITUDE: 10 668 m (35 000 FT)

PAYLOAD: 7256 KG (16 000 LB)

ALTITUDE VARIATION

TRIP DISTANCE N.MI.	+610 m (+2000 FT)				-1219 m (-4000 FT)				-2438 m (-8000 FT)			
	$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN	
	KG (LB)	%			KG (LB)	%			KG (LB)	%		
300	0 ( 0)	0	1		91 ( 200)	2.7	0		181 ( 400)	5.3	0	
500	-45 (-100)	-0.9	1		227 ( 500)	4.6	0		454 (1000)	9.3	-1	
750	-91 (-200)	-1.3	0		317 ( 700)	4.6	-1		771 (1700)	11.3	-3	
1000	-136 (-300)	-1.6	1		454 (1000)	5.2	-1		1134 (2500)	12.9	-3	
1750	-45 (-100)	-0.3	0		726 (1600)	4.9	-3		2041 (4500)	13.6	-7	

WEIGHT VARIATION

TRIP DISTANCE N.MI.	6803 KG (15 000 LB)				4535 KG (10 000 LB)				-4535 KG (-10 000 LB)			
	$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN	
	KG (LB)	%			KG (LB)	%			KG (LB)	%		
300	272 ( 600)	8.0	-		181 ( 400)	5.3	-		-227 ( -500)	-6.7	-	
500	408 ( 900)	8.3	-		363 ( 800)	7.4	-		-317 ( -700)	-6.5	-	
750	590 (1300)	8.6	-		363 ( 800)	5.3	-		-544 (-1200)	-8.0	-	
1000	816 (1800)	9.3	-		499 (1100)	5.7	-		-680 (-1500)	-7.7	-	
1750	1542 (3400)	10.3	-		1043 (2300)	7.0	-		-1224 (-2700)	-8.2	-	

MACH NUMBER VARIATION

TRIP DISTANCE N.MI.	+.02				-.02			
	$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN	
	KG (LB)	%			KG (LB)	%		
300	45 (100)	1.3	0		0 ( 0)	0	1	
500	45 (100)	0.9	-1		0 ( 0)	0	1	
750	45 (100)	0.7	-2		-45 (-100)	-0.7	2	
1000	91 (200)	1.0	-2		-91 (-200)	-1.0	3	
1750	227 (500)	1.5	-4		-91 (-200)	-0.6	3	



TABLE 3-6

## OPERATIONS SENSITIVITY DC-8-20

BASELINE: MACH NO: .80

ALTITUDE: 10 668 m (35 000 FT)

PAYLOAD: 6712 KG (14 800 LB)

## ALTITUDE VARIATION

TRIP DISTANCE N.MI.	+1219 m (+4000 FT)			-1219 m (-4000 FT)			-2438 m (-8000 FT)		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)	°		KG (LB)	°		KG (LB)	°	
500	-363 (-800)	-4.4	-1	408 (900)	5.0	-1	998 (2 200)	12.2	-2
1000	-862 (-1900)	-5.9	0	1134 (2500)	7.8	-2	2676 (5 900)	18.4	-4
1500	-1270 (-2800)	-6.0	0	1859 (4100)	8.8	-3	4399 (9 700)	20.9	-6
2000	-1361 (-3000)	-4.9	0	2494 (5500)	8.9	-4	5986 (13 200)	21.4	-8
2500	-1451 (-3200)	-4.1	0	2993 (6600)	8.5	-5	7438 (16 400)	-21.1	-10

## WEIGHT VARIATION

TRIP DISTANCE N.MI.	+4535 KG (+10 000 LB)			-4535 KG (-10 000 LB)		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)	°		KG (LB)	°	
500	227 (500)	2.8	-	-227 (-500)	-2.8	-
1000	408 (900)	2.8	-	-454 (-1000)	-3.1	-
1500	680 (1500)	3.2	-	-635 (-1400)	-3.0	-
2000	952 (2100)	3.4	-	-862 (-1900)	-3.1	-
2500	1270 (2800)	3.7	-	-1179 (-2600)	-3.3	-

## MACH NUMBER VARIATION

TRIP DISTANCE N.MI.	+.02			-.02		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)	°		KG (LB)	°	
500	136 (300)	1.7	-1	-91 (-200)	-1.1	1
1000	363 (800)	2.5	-3	-227 (-500)	-1.6	2
1500	680 (1500)	3.2	-4	-317 (-700)	-1.5	4
2000	952 (2100)	3.4	-6	-454 (-1000)	-1.6	6
2500	1270 (2800)	3.6	-7	-544 (-1200)	-1.5	6

TABLE 3-7  
OPERATIONS SENSITIVITY DC-8-51/-52

BASELINE: MACH NO: .80

ALTITUDE: 10 668 m (35 000 FT)

PAYLOAD: 1483 KG (16 500 LB)

ALTITUDE VARIATION

TRIP DISTANCE N.M.I.	+1219 m (+4000 FT)			-1219 m (-4000 FT)			-2438 m (-8000 FT)		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)			KG (LB)			KG (LB)		
500	-227 (-500)	-3.4	0	454 (1000)	6.8	-1	1043 (2 300)	15.5	-2
1000	-680 (-1500)	-5.7	0	1088 (2400)	9.1	-2	2540 (5 600)	21.2	-4
1500	-998 (-2200)	-5.7	0	1723 (3800)	9.9	-3	4036 (8 900)	23.2	-6
2000	-1224 (-2700)	-5.3	0	2358 (5200)	10.3	-4	5333 (12 200)	24.1	-8
2500	-1361 (-3000)	-4.7	0	2857 (6300)	9.9	-5	6848 (15 100)	23.8	-10

WEIGHT VARIATION

TRIP DISTANCE N.M.I.	+9070 KG (20 000 LB)			+4535 KG (10 000 LB)			-4535 KG (-10 000 LB)		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)			KG (LB)			KG (LB)		
500	408 (900)	6.1	-	227 (500)	3.4	-	-181 (-400)	-2.7	-
1000	726 (1600)	6.1	-	317 (700)	2.7	-	-317 (-700)	-2.7	-
1500	1088 (2400)	6.3	-	499 (1100)	2.9	-	-499 (-1100)	-2.9	-
2000	1542 (3400)	6.7	-	726 (1600)	3.2	-	-635 (-1400)	-2.8	-
2500	1995 (4400)	6.9	-	957 (2100)	3.3	-	-907 (-2000)	-3.2	-

MACH NUMBER VARIATION

TRIP DISTANCE N.M.I.	+.02			-.02		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)			KG (LB)		
500	136 (300)	2.0	-1	-91 (-200)	-1.4	1
1000	363 (800)	3.0	-3	-272 (-600)	-2.3	3
1500	590 (1300)	3.4	-4	-408 (-900)	-2.4	4
2000	867 (1900)	3.8	-6	-590 (-1300)	-1.6	6
2500	1088 (2400)	3.9	-7	-816 (-1800)	-2.8	7

TABLE 3-8

## OPERATIONS SENSITIVITY DC-8-61

BASELINE: MACH NO: .80

ALTITUDE: 10 668 m (35 000 FT)

PAYLOAD: 9388 KG (20 700 LB)

## ALTITUDE VARIATION

TRIP DISTANCE N.M.I.	+1219 m (+4000 FT)				-1219 m (-4000 FT)				-2438 (-8000 FT)			
	$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN	
	KG (LB)				KG (LB)				KG (LB)			
500	-136 (-300)	-1.9	0		363 (800)	4.9	0		862 (1 900)	11.7	-1	
1000	-363 (-800)	-2.8	-1		907 (2000)	7.0	-2		2222 (4 900)	17.1	-4	
1500	-363 (-800)	-1.9	-1		1406 (3100)	7.4	-3		3537 (7 800)	18.7	-6	
2000	-408 (-900)	-1.6	0		1859 (4100)	7.4	-4		4762 (10 500)	19.0	-8	
2500	-408 (-900)	-1.3	0		2177 (4800)	6.9	-5		5805 (12 800)	18.4	-10	

## WEIGHT VARIATION

TRIP DISTANCE N.M.I.	+9070 KG (20 000 LB)				+4535 KG (10 000 LB)				-4535 KG (-10 000 LB)			
	$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN	
	KG (LB)				KG (LB)				KG (LB)			
500	499 (1100)	6.8	-		227 (500)	3.1	-		-227 (-500)	-3.1	-	
1000	862 (1900)	6.6	-		408 (900)	3.1	-		-363 (-800)	-2.8	-	
1500	1361 (3000)	7.2	-		635 (1400)	3.4	-		-590 (-1300)	-3.1	-	
2000	1995 (4400)	8.0	-		907 (2000)	3.6	-		-862 (-1900)	-3.4	-	
2500	2721 (6000)	8.6	-		1315 (2900)	4.2	-		-1134 (-2500)	-3.6	-	

## MACH NUMBER VARIATION

TRIP DISTANCE N.M.I.	+.02				-.02			
	$\Delta$ FUEL		$\Delta$ TIME MIN		$\Delta$ FUEL		$\Delta$ TIME MIN	
	KG (LB)				KG (LB)			
500	136 (300)	1.9	-1		-91 (-200)	-1.2	1	
1000	317 (700)	2.4	-3		-227 (-500)	-1.7	1	
1500	499 (1100)	2.6	-4		-408 (-900)	-2.2	4	
2000	726 (1600)	2.9	-5		-644 (-1400)	-2.2	6	
2500	998 (2200)	3.2	-6		-860 (-1900)	-2.2	7	

TABLE 3-9

## OPERATIONS SENSITIVITY DC-8-62

BASELINE: MACH NO: .80

ALTITUDE: 10 668 m (35 000 FT)

PAYLOAD: 7800 KG (17 200 LB)

## ALTITUDE VARIATION

TRIP DISTANCE N.MI.	+1219 m (+4000 FT)			-1219 m (-4000 FT)			-2438 m (-8000 FT)		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)			KG (LB)			KG (LB)		
500	-181 (-400)	-2.8	0	408 (900)	6.3	-1	907 (2 000)	14.1	-2
1000	-590 (-1300)	-5.2	0	998 (2200)	8.7	-2	2 268 (5 000)	19.6	-4
2000	-1270 (-2800)	-5.8	1	2132 (4700)	9.8	-4	5 034 (11 100)	23.1	-8
3000	-1587 (-3500)	-4.8	1	3175 (7000)	9.7	-6	7 619 (16 800)	23.2	-12
4500	-1859 (-4100)	-3.6	1	4354 (9600)	8.5	-9	10 975 (24 200)	21.5	-19

## WEIGHT VARIATION

TRIP DISTANCE N.MI.	+9070 KG (20 000 LB)			+4535 KG (10 000 LB)			-4535 KG (-10 000 LB)		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)			KG (LB)			KG (LB)		
500	363 (800)	5.6	-	181 (400)	2.8	-	-136 (-300)	-2.1	-
1000	590 (1300)	5.2	-	272 (600)	2.4	-	-272 (-600)	-2.4	-
2000	1224 (2700)	5.6	-	590 (1300)	2.7	-	-499 (-1100)	-2.3	-
3000	1995 (4400)	6.1	-	952 (2100)	2.9	-	-862 (-1900)	-2.6	-
4500	3810 (8400)	7.5	-	1859 (4100)	3.6	-	-1678 (-3700)	-3.3	-

## MACH NUMBER VARIATION

TRIP DISTANCE N.MI.	+.02			-.02		
	$\Delta$ FUEL		$\Delta$ TIME MIN	$\Delta$ FUEL		$\Delta$ TIME MIN
	KG (LB)			KG (LB)		
500	136 (300)	2.1	-1	-45 (-100)	-0.7	1
1000	363 (800)	3.2	-3	-227 (-500)	-2.0	2
2000	816 (1800)	3.8	-5	-449 (-1100)	-2.3	6
3000	1361 (3000)	4.2	-8	-862 (-1900)	-2.6	9
4500	2404 (5300)	4.7	-13	-1315 (-2900)	-2.6	12

TABLE 3-10  
OPERATIONS SENSITIVITY DC-10-10

BASELINE: MACH NO: .83

ALTITUDE: 10 668 m (35 000 FT)

PAYLOAD: 12 608 KG (27 800 LB)

ALTITUDE VARIATION

TRIP DISTANCE N.MI.	+1219 m (+4000 FT)			-1219 m (-4000 FT)			-2438 m (-8000 FT)		
	FUEL KG (LB)	Δ TIME MIN		FUEL KG (LB)	Δ TIME MIN		FUEL KG (LB)	Δ TIME MIN	
500	-327 (-700)	-2.7	-1	363 (800)	4.4	-1	352 (-700)	11.1	-
1000	-635 (-1400)	-4.3	0	1134 (2500)	7.7	-2	1676 (-1400)	18.1	-4
1500	-996 (-2200)	-4.6	0	1859 (4100)	8.6	-3	4167 (-2200)	19.1	-6
2000	-1008 (-2400)	-3.8	0	2494 (5500)	8.7	-4	5150 (-2400)	20.1	-7
2500	-1081 (-2400)	-3.1	0	3175 (7000)	8.9	-5	7391 (-1600)	20.7	-10

WEIGHT VARIATION

TRIP DISTANCE N.MI.	+9070 KG (20 000 LB)			+4535 KG (10 000 LB)			-4535 KG (-10 000 LB)		
	FUEL KG (LB)	Δ TIME MIN		FUEL KG (LB)	Δ TIME MIN		FUEL KG (LB)	Δ TIME MIN	
500	317 (700)	3.8	-	136 (300)	1.6	-	-111 (-400)	-2.3	-
1000	590 (1300)	4.0	-	272 (600)	1.6	-	-227 (-500)	-1.5	-
1500	863 (1900)	4.0	-	408 (900)	1.9	-	-363 (-800)	-1.7	-
2000	1134 (2500)	4.0	-	544 (1200)	1.9	-	-444 (-1000)	-1.9	-
2500	1542 (3400)	4.3	-	726 (1600)	2.0	-	-630 (-1500)	-1.9	-

MACH NUMBER VARIATION

TRIP DISTANCE N.MI.	-0.01		
	FUEL KG (LB)	Δ TIME MIN	
500	-45 (-100)	-0.6	0
1000	-91 (-200)	-0.6	1
1500	-131 (-400)	-0.6	2
2000	-172 (-600)	-1.0	3
2500	-317 (-700)	-0.9	4

TABLE 3-11  
OPERATIONS SENSITIVITY 747-100

BASELINE: MACH NO: .84

ALTITUDE: 10 668 m (35 000 FT)

PAYLOAD: 17 506 KG (38 600 LB)

ALTITUDE VARIATION

TRIP DISTANCE N.M.I.	+1219 m (+4000 FT)			-1219 m (-4000 FT)			-2438 (-8000 FT)		
	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN
	KG (LB)			KG (LB)			KG (LB)		
500	-181 (-400)	-1.4	-1	590 (1 300)	4.5	-1	1 542 (3 400)	11.9	-2
1000	-771 (-1700)	-3.4	-1	1587 (3 500)	7.0	-2	3 991 (8 800)	17.7	-4
2000	-1723 (-3800)	-4.1	0	3537 (7 800)	8.3	-4	8 707 (19 200)	20.5	-8
3000	-1995 (-4400)	-3.1	0	5261 (11 600)	8.3	-5	13 107 (28 900)	20.6	-12
4000	-2086 (-4600)	-2.4	-1	6712 (14 800)	7.8	-8	17 098 (37 700)	19.9	-17

WEIGHT VARIATION

TRIP DISTANCE N.M.I.	18 141 KG (40 000 LB)			9070 KG (20 000 LB)			-9070 KG (-20 000 LB)		
	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN
	KG (LB)			KG (LB)			KG (LB)		
500	726 (1 600)	5.6	-	363 (800)	2.8	-	-317 (-700)	-2.4	-
1000	1179 (2 600)	5.2	-	590 (1300)	2.6	-	-544 (-1200)	-2.4	-
2000	2313 (5 100)	5.4	-	1134 (2500)	2.7	-	-1088 (-2400)	-2.6	-
3000	3719 (8 200)	5.9	-	1769 (3900)	2.8	-	-1678 (-3700)	-2.6	-
4000	5760 (12 700)	6.7	-	2721 (6000)	3.2	-	-2449 (-5400)	-2.9	-

MACH NUMBER VARIATION

TRIP DISTANCE N.M.I.	+.02			-.02		
	Δ FUEL		Δ TIME MIN	Δ FUEL		Δ TIME MIN
	KG (LB)			KG (LB)		
500	181 (400)	1.4	-1	-91 (-200)	-0.7	1
1000	454 (1000)	2.0	-2	-272 (-600)	-1.2	2
2000	1088 (2400)	2.6	-5	-635 (-1400)	-1.5	5
3000	1769 (3900)	2.8	-7	-1043 (-2300)	-1.7	8
4000	2630 (5800)	3.1	-1	-1224 (-2700)	-1.4	9

Mach Number Variation.-- The Mach number range investigated was  $\pm .02$  from baseline. The study indicates fuel consumption could be reduced from 1/2% to as much as 3% by reducing cruise Mach number by 0.02. In many cases, the resulting speed would be essentially that shown by the airplane manufacturer as the speed for maximum range. The speed stability characteristics of current jet transport airplanes in this region tend to be such that it is questionable whether or not the fuel saving noted above could be realized.

Increasing Mach number by .02 yields consumption increases ranging from 1-1/2% to 5%.

### SEATING DENSITY SENSITIVITY

Holding total airplane-seat-miles constant, fuel efficiency is improved by increasing the number of seats per airplane and reducing the total airplane miles. Table 2-18 illustrated the fuel efficiency improvement potential of higher density seating. Table 3-12 shows the percentage increase in seating density from the base year 1973 based on the seat quantities indicated in table 2-19. These percentages approximate the fuel efficiency improvements. In the "Increased Density Estimate" column of table 3-12 it is seen that the 727 and 737 increases are small compared to the other aircraft. This is because the 737 and 727-200 coach sections already have the objective .864 m (34 in) seat pitch and the 727-100 pitch cannot be reduced as discussed in section 2. In the "March 1976 In-Service" column, the DC-8-61, DC-8-62 and 747 aircraft show substantial improvement over the base year. In the case of the DC-8's, this is because the 6-across two-by-two coach seating has replaced the 5-across seating of 1973. The 747 improvement is due to removal of the coach lounge discussed in section 2.

Due to the 5-across DC-8 seating, use of 1973 as a comparative base is considered misleading. The table 3-12 percentage improvement from 1973 to the increased density estimate is simply not available today. Accordingly, table 3-13 has been developed using current seating configurations as the baseline. Measurable increases in fuel efficiency still would be achieved with the higher density seating. Figure 3-1 graphically displays the seat-mile fuel efficiency of each of the study fleets showing the 1973, 1975 and increased seating densities.

TABLE 3-12  
SEATING RELATIONSHIPS  
1973 BASE

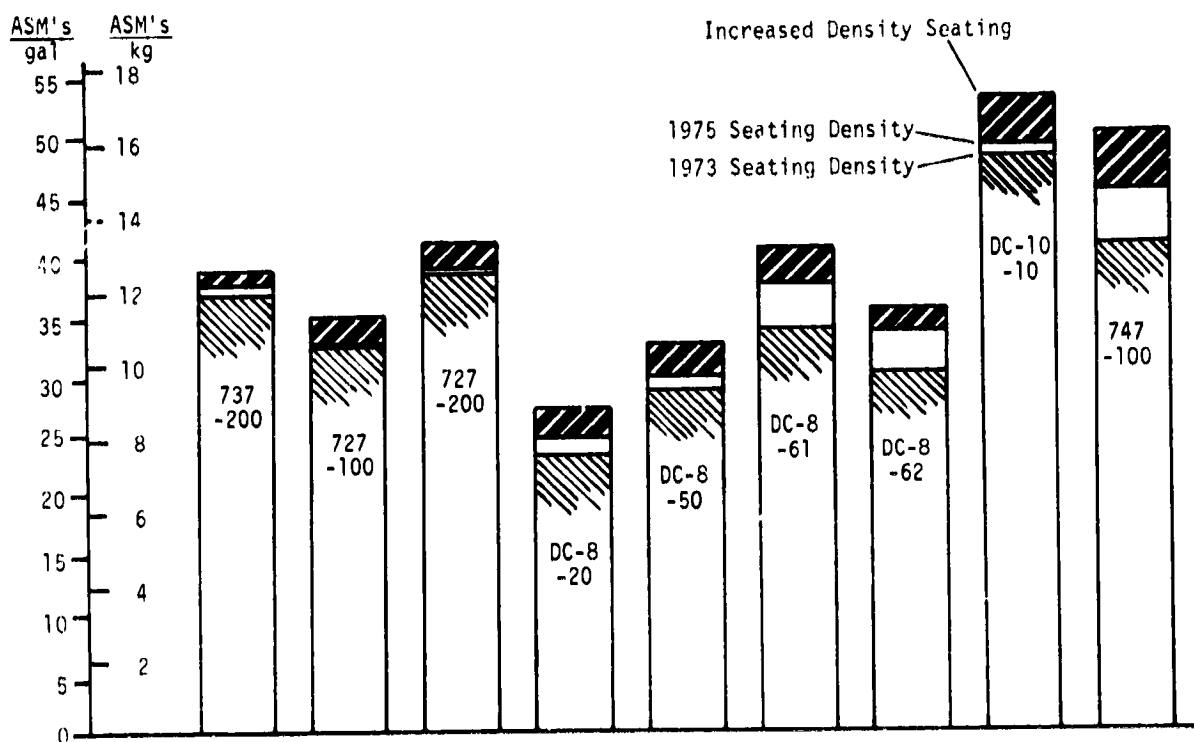
	1973 Actual Average	March 1976 In-Service	Increased Density Estimate
737-200	Base ↓	2.6%	4.8%
727-100		1.3	5.5
727-200		2.6	7.5
DC-8-20		7.1	15.3
DC-8-50		5.3	13.5
DC-8-62		12.0	16.7
DC-8-61		11.3	19.7
DC-10-10		3.6	10.5
747-100		10.9	22.3

TABLE 3-13  
SEATING RELATIONSHIPS  
1976 BASE

	1973 Actual Average	March 1976 In-Service	Increased Density Estimate
737-200	- 2.5%	Base ↓	2.1%
727-100	- 1.3		4.1
727-200	- 2.5		4.8
DC-8-20	- 6.6		7.8
DC-8-50	- 5.0		7.8
DC-8-62	-10.7		4.2
DC-8-61	-10.1		7.6
DC-10-10	- 3.5		6.6
747-100	- 9.8		10.3



Figure 3-1  
Fuel Efficiency  
(1000 N Mi Trip Distance)



## SECTION 4

### OPTIONS SELECTED FOR ECONOMIC ANALYSIS

Midway through the study, all of the contractors and the NASA Technical Monitor conferred to select the fuel conserving options that would be the subject of payback or return on investment analysis. Also, assumptions were standardized during this meeting as to (1) the magnitude of fuel savings associated with retrofit options and (2) the data baselines to which the savings would be applied.

#### SELECTED OPTIONS

The options selected are classed as follows:

- Retrofit modifications applied to existing fleet aircraft.
- Fuel efficient derivatives of aircraft types currently in production.
- New near-term (1980 introduction) turbofan aircraft.
- Advanced state-of-the-art turboprop aircraft (1985 introduction).

Retrofit Modifications.-- Table 4-1 identifies the retrofit modifications and the fuel reduction percentage used in the financial analysis. Some broad assumptions were made for convenience purposes. For instance, fuel savings estimated by Douglas for the DC-9 were allowed to apply to United's 727 and 737 aircraft and the average of the Douglas estimate for the DC-10 and the Lockheed estimate for the L-1011 were used for the DC-10, L-1011 and 747. The 7½% savings indicated in table 4-1 was not applied directly to the DC-10/747 1973 fuel burn data set forth for section 2; rather, the 1973 fuel efficiency level was allowed to deteriorate to a half-fleet-life level before applying the 7½%. This service life deterioration adjustment is discussed in greater depth later in this section.

Derivative Aircraft.-- The derivative aircraft studied are described below. Each configuration would be a derivative of an airplane currently in production at Lockheed, Douglas or Boeing.

- L-1011 Short Body -- A 200 passenger version that would be 21'8" shorter than the standard L-1011. The maximum takeoff weight would be 147,420 kgs (325,000 lbs) compared to the standard's 195,048 kgs (430,000 lbs). Three Rolls Royce RB.211-22P engines would be retained but operated at a lower thrust level.

TABLE 4-1  
RETROFIT MODIFICATIONS

Retrofit Modifications	Aircraft	Fuel Savings
<ul style="list-style-type: none"> <li>Winglets and general drag reduction studied by Douglas</li> <li>Wing tip extension and engine afterbody improvements studied by Lockheed</li> </ul>	DC-10 L-1011 747	7%
<ul style="list-style-type: none"> <li>Winglets and general drag reduction studied by Douglas</li> </ul>	DC-8-20 DC-8-50 DC-8-61	5%
	DC-9 727 737	4%
<ul style="list-style-type: none"> <li>Winglets</li> </ul>	DC-8-62	2%
<ul style="list-style-type: none"> <li>Re-engining with JT8D-209 (refan) plus above winglet and drag reducing modifications</li> </ul>	DC-8-20	28%
	DC-8-50 DC-8-61	15%
<ul style="list-style-type: none"> <li>JT8D-209 refan plus winglets</li> </ul>	DC-8-62	12%

- L-1011 Long Body -- The change from the standard airplane is primarily a 9m (30 ft) (approx.) stretch and the installation of higher thrust RB.211-524 engines. The 407 seats denoted by Lockheed reflect a 9-across coach section plus 44 seats in a lower deck compartment.
- DC-10-10D -- Though similar in capacity (199 seats) to the Short Body L-1011, the DC-10-10D changes from its parent are greater. There would be two CF6-50C engines compared to three CF6-6D's on the DC-10-10. Also, the derivative would incorporate (1) composite materials in secondary structure, (2) a supercritical wing, and (3) general weight and drag reducing improvements.
- DC-10-40D -- In addition to a 9m (30 ft) stretch, this derivative would include winglets, composites in secondary structure areas and the general weight and drag reducing improvements. Douglas lists the passenger capacity at 327.
- 727-300 -- The data approximations for this derivative have been taken from United's files; e.g., it is not based on airframe contractor supplied data as in the case of the DC-10 and L-1011 derivatives. The body would be 5.6m (18.3 ft) longer than the 727-200 and interior configurations from 156 to 158 seats have been studied. The engines would be JT8D with a new front fan -- specifically the JT8D-217. There are no advanced technologies such as composite structures but it does include an improved performance wing.

New Near-Term Aircraft (NNT).-- Three families of near term aircraft (excluding turboprops) were studied by Douglas and Lockheed. Near term was defined as a 1980 introduction date thus constraining the designs to current state-of-the-art or at most minor advancement.

The three families of aircraft, all wide-body, were:

- 200 passengers, 1500 n mi range
- 200 passengers, 3000 n mi range
- 400 passengers, 3000 n mi range

and, within each family three designs were developed. The optimization criteria for the three designs were:

- Minimum DOC with a \$79/m<sup>3</sup> (30¢/gal) fuel cost
- Minimum DOC with a \$158/m<sup>3</sup> (60¢/gal) fuel cost
- Minimum fuel consumption

The first two criteria assume no limitations on fuel availability and supply and demand factors determine price. The third criterion assumes a rationing or quasi-rationing situation and minimum fuel burn is sought independent of price.

Douglas and Lockheed combined their study efforts and provided a single set of data for the nine configurations. This combining of data was done in order to reduce United's analysis workload to a manageable level.

In addition to the above near-term aircraft, an abbreviated analysis was made of the Boeing 7X7. Boeing is continually evaluating the characteristics of this vehicle in light of customer needs projected for the 1980's and therefore, the estimated data used in this study is fluid. Some of the basic characteristics that we used were a wide-body interior, JT10D/CFM-56 powerplant class, and an advanced airfoil. The number of seats used for the purposes of this analysis was 193.

Advanced Turboprop.-- The turboprop introductory target was set at 1985, therefore this vehicle would incorporate technological advancements beyond the new near-term airplanes. Lockheed identified these technologies which would be used in addition to an advanced prop-fan design:

- Increased use of composites
- Supercritical airfoil
- Active controls for relaxed longitudinal stability and gust alleviation

The basic design is a wide-body 200 passenger, 1500 n mi airplane. The design cruise speed is Mach .80 selected to be competitive speed-wise with DC-9's, 727's, etc. Whether or not such a speed is necessary to achieve a successful introduction is explored in the "Turboprop Consumer Research Study" section.

## AIRLINE ADJUSTMENT FACTORS

### Service Life Adjustment

A primary task for United was the documentation of the fleet as it existed in 1973. The retrofit modification fuel savings shown in table 4-1 were applied to this baseline fleet. The savings were applied directly to the "mature" fleets to obtain expected values of fuel consumption. However, as cited earlier, since the wide-body fleets (747, DC-10 and L-1011) were new airplanes during the 1973 base year and had not reached the middle of their service life, some adjustment had to be made to the UAL operational data for these fleets.

Such a service life adjustment is necessary because the efficiency of the airplane/engine combination deteriorates with time and use. The sources of

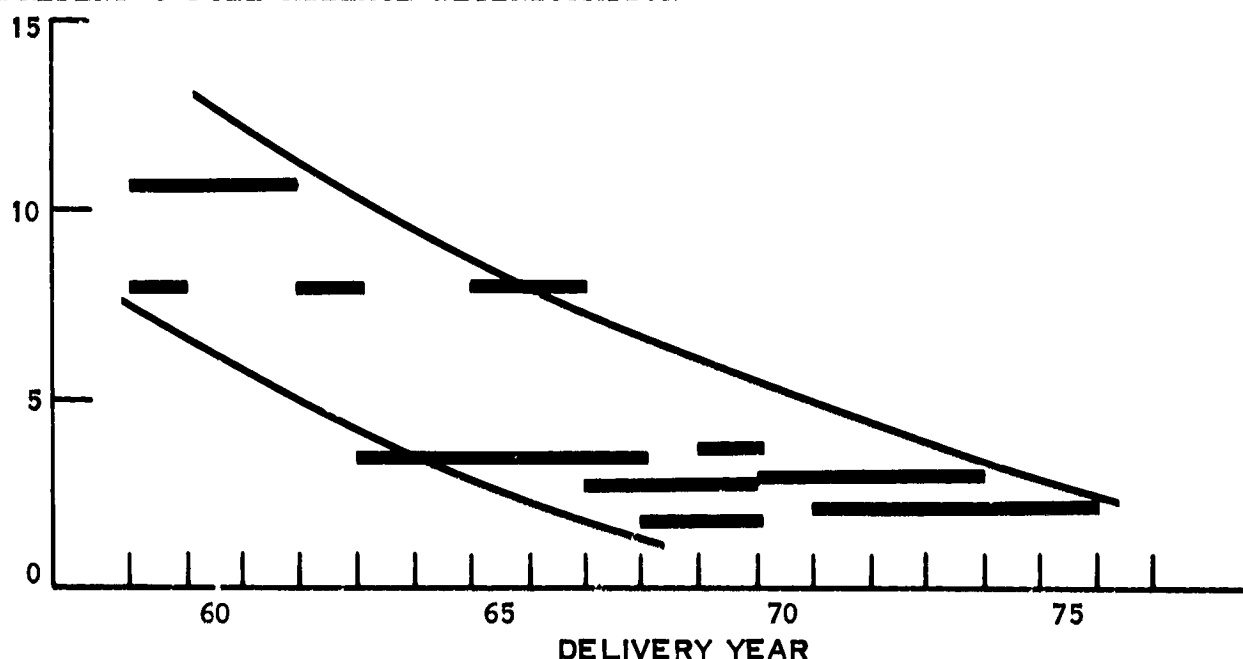
deterioration are no mystery but one may question why the systems are not restored. The answer is that in many instances total restoration is not economical, even with relatively high fuel prices. From an economic standpoint, the level of deterioration which is tolerated is determined by a balance of higher fuel consumption on one side and labor and material costs for restoration on the other side.

Figure 4-1 presents deviation of current fleet fuel consumption from the consumption performance when a fleet was new. Also shown are delivery periods for each fleet. An approximate deterioration band indicates that aircraft in the middle of their service life would experience about 4-5% greater fuel consumption than when new.

The average ages of the UAL wide-body fleets during the 1973 base year were 1.9 years for the 747 and 1.1 years for the DC-10. Figure 4-1 indicates that the fuel consumption due to combined airframe and engine deterioration increases approximately 0.6% per year. Therefore, the adjustments applied to the wide-body 1973 UAL operational data for service life were 3½% for the 747 and 4½% for the DC-10.

Figure 4-1  
Service Life Adjustment

PRESENT % FUEL MILEAGE DETERIORATION



### Block Fuel and Time Airline Adjustment Factors

Actual airline operations tend to require more fuel and time than is predicted by airplane manufacturers' data. This is the result of many operational variables such as delays, ATC routing, airplane performance deterioration, etc., which the manufacturer cannot take into account. Since the analysis of this project included actual historical data for an operational fleet as well as predicted data for new designs, it was necessary to place all data to be used on an equal basis.

Adjustment factors were developed jointly by all the contractors and the NASA Technical Monitor. The factors were developed from a comparison of manufacturer's original (handbook) data and actual airline in-service operational data were compared. In each case, the difference between the two data sets was expressed as a function of stage length. The block time data for the two airplanes showed good agreement. However, the block fuel data for the two airplanes were consistently different. The block time data were expected to agree since the operational variables which tend to increase block time would affect both fleets in the same way. The block fuel difference between the two fleets was also expected since one fleet was mature and the other was essentially new, not having experienced significant airplane/engine performance deterioration. The final fairing through the data, which is shown in figure 4-2, accounts for such deterioration for mid-life aircraft. These adjustment factors were applied to manufacturer predicted data for the derivative, the new near-term and the advanced turboprop aircraft to achieve a common set of data which is representative of actual airline operation for mid-life aircraft. Actual airline historical data was used for the retrofit options except for the wide-body service life adjustment discussed above.

The service life adjustment and the airline block fuel and time adjustments that were used to place data for all airplane options on the same basis are summarized in table 4-2. The block time factor was used to actually increase time related unit costs, but was not applied to the block time per se since this would tend to increase the utilization and thereby understate depreciation and other fixed annual costs.

Figure 4-2  
Operational Factors

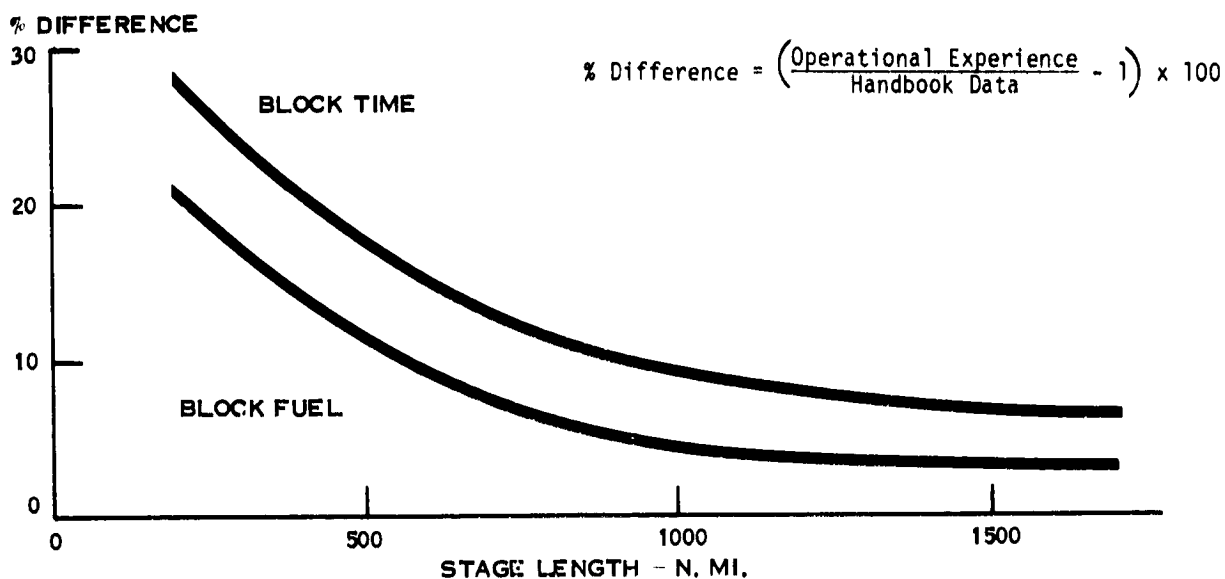


TABLE 4-2  
ADJUSTMENT FACTOR APPLICATION SUMMARY

Option	Base Data	Fuel	Time
1973 Baseline Fleet	UAL operational	--	--
'73 Fleet Adjusted to Mid Service Life	UAL 1973 Base-line Fleet	Service Life 747 & DC-10	--
Retrofit Modifications	'73 Fleet Adj. to Mid Service Life	Mfr'g. Fuel Savings Increment Projections	--
Derivatives	Mfr'g. Predicted	Airline Factor	Airline Factor
New Near-Term Designs	Mfr'g. Predicted	Airline Factor	Airline Factor
Turboprop	Mfr'g. Predicted	Airline Factor	Airline Factor



### Range Capability

Range data supplied by the airplane manufacturers must be modified somewhat for airline use. Such data is usually presented for zero-wind, standard day conditions and for a given design point. In this study, the zero-wind range of an airplane carrying full passengers and bags was adjusted to account for the 90% probability winter headwinds on the anticipated routes for that design. This adjusted maximum range was then used as the upper limit for scheduling the design. A further consideration then becomes the actual distances of the routes on which the design is used. An example of this process is shown below for the new near-term airplane designs.

<u>New Near-Term Design</u>	<u>Max. Useful Range</u>	<u>Type Replaced</u>	<u>Avg. Scheduled Range</u>
1500 N. Mi. 200 psgr.	1250 N Mi	727-100 & 200	530 N Mi
3000 N. Mi. 200 psgr.	2500	DC-8-61	930
3000 N. Mi. 400 psgr.	2500	DC-10-10 & 747	1320

It is obvious that the manufacturers' design range is considerably different from the actual range of the airplane in scheduled service. The actual ranges scheduled depend on an airline's route structure, fleet mix and competition. The example above indicates the 1500 n mi/200 psgr. design would be used to replace the 727 fleet. Since the average scheduled range is only 530 n mi, it might appear that both the design range of 1500 n mi and the maximum useful range of 1250 n mi are excessive. However, the 727-100 fleet has a maximum useful range which is greater than that of the replacement airplane; it is presently used on such routes as Chicago-San Francisco (over 1600 n mi). It's obvious the new design would not perform adequately on that route and, therefore, is not a direct replacement for the 727. However, it could be used as a 727 replacement on many routes if the longer 727 routes were serviced by another airplane type, already in service with the airline, such as the DC-8 or DC-10.

## SECTION 5

### ANALYSIS OF AIRCRAFT MODIFICATIONS, DERIVATIVE AIRCRAFT, TURBOPROP AND NEW NEAR-TERM FUEL CONSERVING AIRCRAFT

#### FUEL EFFICIENCY

Fuel efficiency can show measurable improvements with any of the following alternatives studied during this program:

- Increased density seating
- Increased load factors
- Retrofit modifications
- Derivative aircraft
- New near-term aircraft
- Advanced prop-fan aircraft

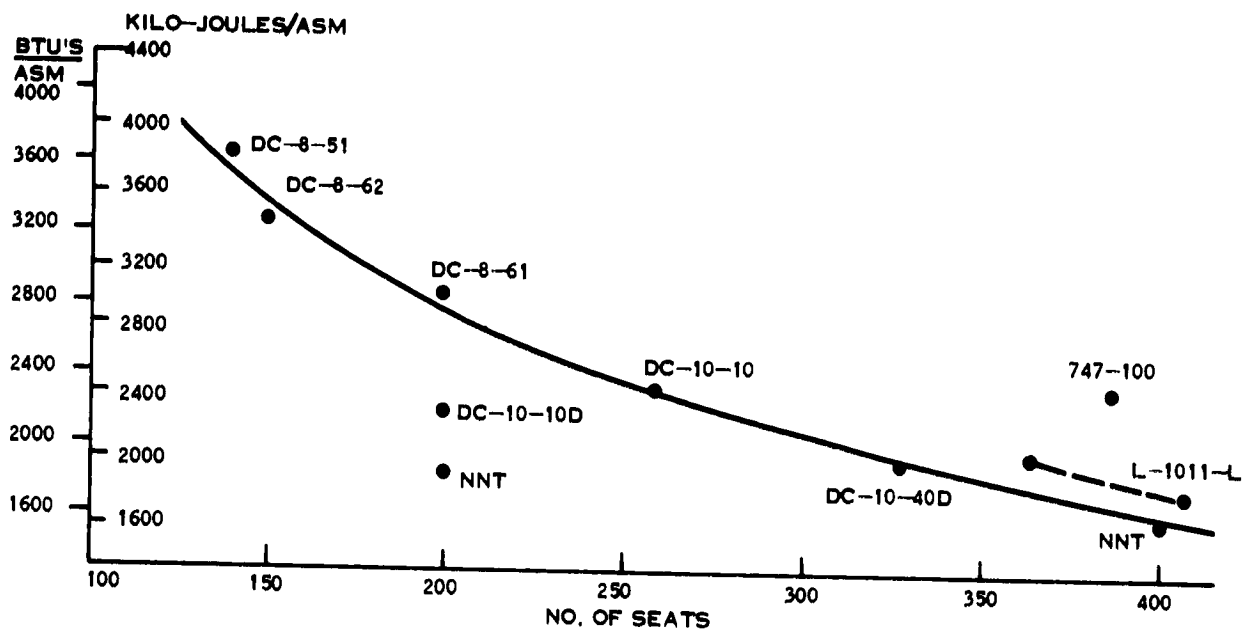
The fuel efficiency benefits of higher density seating are illustrated in both table 2-18 and figure 3-1. Increasing load factors produce similar improvements when the efficiency is measured on a revenue-passenger-mile basis. However, it is important to note that such density increases might result in an increase in total fuel consumed. This can happen if the density increases produce lower passenger unit costs that lead to lower fares and, in turn, an increased demand for air travel that requires additional flights.

Figure 5-1 is a plot of fuel efficiency relative to aircraft seating capacity. This chart compares the intermediate/long haul aircraft at a 2000 n mi stage length. The DC-8, DC-10-10 and 747-100 seating selected for this comparison is the increased density seating tabulated in column (5) of table 2-19.

The curve shown in figure 5-1 indicates that fuel efficiency, as measured on a seat-mile basis, increases with larger capacity airplanes. However, there is also a technology contribution to this trend line. The DC-10-10 has high bypass engines which are more efficient than the DC-8 low bypass engines; the DC-10-10D would incorporate additional advanced technologies as described in section 4. The new near-term aircraft efficiencies result primarily from basic aerodynamic design with fuel priced at \$79/m<sup>3</sup> to \$158/m<sup>3</sup> (30¢/gal to 60¢/gal) whereas the other aircraft were born in the \$32/m<sup>3</sup> (12¢/gal) era. The 747 falls above the curve largely because of design parameters different from the other aircraft. For example, its design range is more than double the 2000 n mi stage length being compared in this figure.

The new near-term (NNT) data points shown on the figures in this section are generally applicable to all three NNT design criteria: minimum DOC with \$79/m<sup>3</sup> (30¢/gal) fuel, minimum DOC with \$158/m<sup>3</sup> (60¢/gal) fuel and minimum fuel. This is because the cost and fuel variations between the designs are

Figure 5-1  
FUEL EFFICIENCY  
2000 N. MI. STAGE LENGTH



less than the width of the data point dots on these figures. However, fuel efficiency variations between the designs are included in appendix A which provides fuel consumption and fuel efficiency estimates for all the fuel conserving options. DOC variations are provided in tables 5-2 and 5-3.

Figure 5-2 illustrates graphically the fuel efficiency benefits associated with retrofit modifications applied to our existing intermediate/long haul aircraft. The curves on this figure generally reflect the tabular fuel savings data provided in table 4-1.

A 727-200, new near-term aircraft and turboprop fuel efficiency comparison is provided in figure 5-3. This is a short/medium haul comparison at a 500 n mi stage length. The new near-term and turboprop offer substantial opportunities for increased fuel efficiency. Figure 5-3 includes a DOC comparison for these aircraft as well as the fuel efficiency comparison. Direct operating cost projections for the fuel conserving alternatives are discussed below.

Figure 5-2  
FUEL EFFICIENCY - RETROFIT MODIFICATIONS  
2000 N. MI. STAGE LENGTH

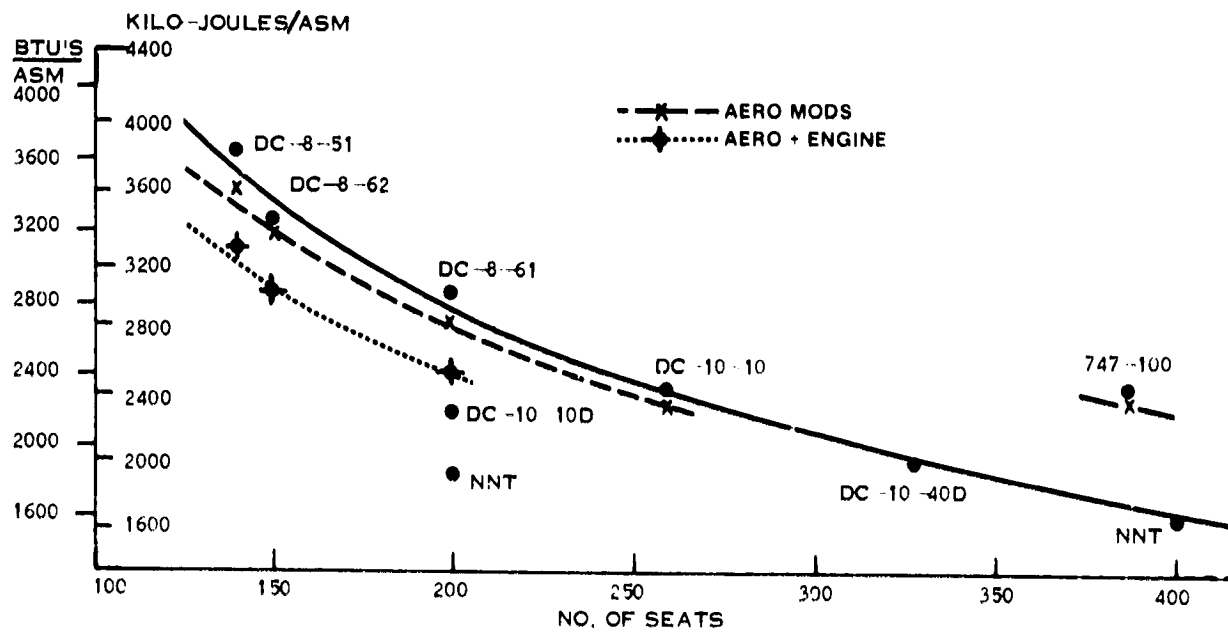
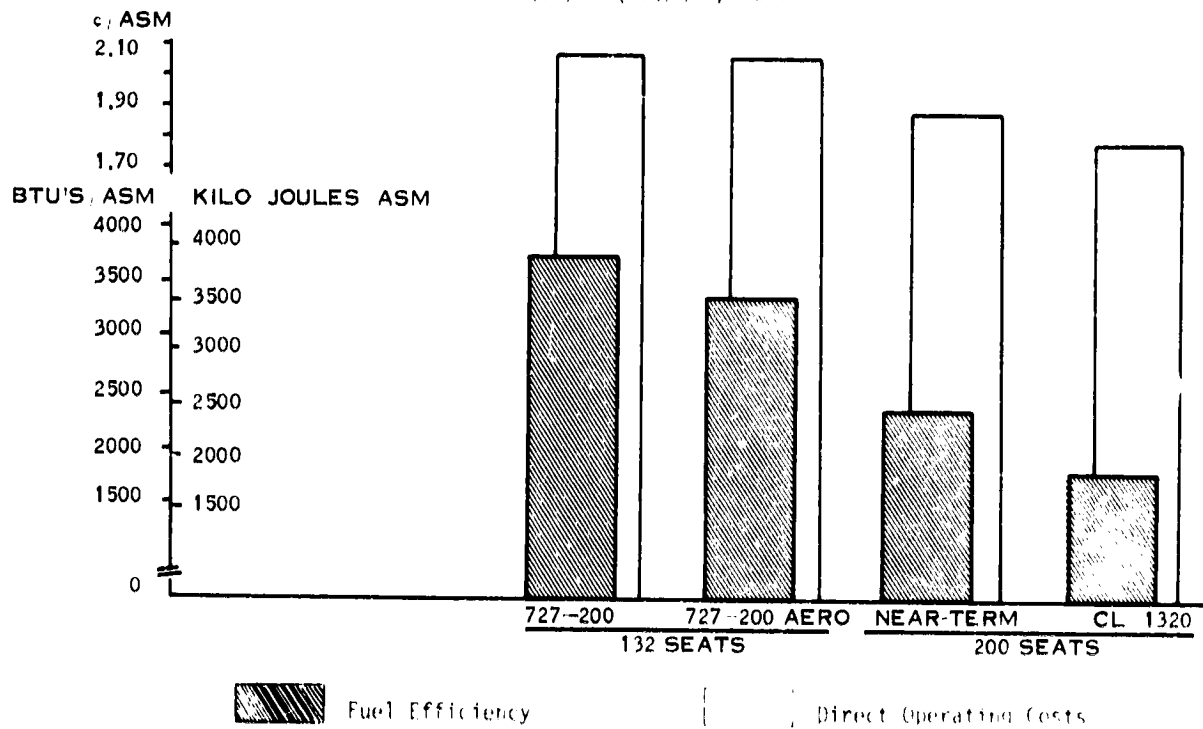


Figure 5-3

FUEL EFFICIENCY - DIRECT OPERATING COSTS

500 N. MI. STAGE LENGTH  
\$79/m<sup>3</sup> (30¢/gal) Fuel



## DIRECT OPERATING COSTS

Direct operating cost estimates for the fuel conserving aircraft were developed using manufacturer data and some of the concepts discussed in sections 2 and 4. Section 2 data applied to a single yearly period, 1973, whereas this phase of the study focused upon three future milestone years -- 1980, 1985 and 1990.

The selection of a modification schedule for the retrofit modifications influences a number of factors including manpower and facilities utilization, fleetwide asset depreciation and the timing of fuel reduction benefits. Table 5-1 shows a retrofit accomplishment schedule that assumes two modification lines each for DC-8's, 727's and 737's and one such line each for the 747 and DC-10. Based on an estimated three week modification period per airplane (whether aero or aero plus engine) seventeen airplanes could be modified per line per year. All retrofit could then be complete by the early part of the third year except the 727 which would require 4½ years. As airlines' maintenance docks could not be tied up this way continuously for 2+ years, reliance on manufacturer or other facilities would be necessary.

TABLE 5-1  
RETROFIT MODIFICATION ACCOMPLISHMENT

Modification Year	Number of Aircraft Retrofits Completed Each Year					
	737-200	727-100/ -200	DC-8-20/ -51/-52	DC-8-61/ -62	DC-10-10	747-100
1	34	34	17	17	17	17
2	27	34	17	17	17	1
3		34	6	5	4	
4		34				
5		14				
No. of Mod. Lines	2	2	1	1	1	1

The table 5-1 schedule reflects an accelerated accomplishment. An alternative would be modification concurrent with an airplane's normal overhaul or heavy maintenance action. Aircraft out-of-service time would be minimized and manpower requirements would be better balanced. We pursued the accelerated schedule, however, for this study for two reasons:

1. This study was initiated when fuel shortage was a crisis situation and accelerated retrofit would yield greater fuel conservation, and
2. The time between major maintenance visits is very long -- 21,000 hours for the DC-8. With an annual average utilization of 3,300 flight-hours, the interval between visits is over six years. Adding a five year retrofit write-off, the operating period after start of retrofit would have to be in excess of eleven years. That eleven years would mean a total operating life of 30 years for some of the DC-8's; and, while such a life may be feasible physically, it is doubtful that it would be accommodated in an investment decision making process.

Tables 5-2 and 5-3 tabulate some of the direct operating cost estimates developed for this phase of the study. Table 5-2 includes the short/medium haul aircraft and the cost data is for a 500 n mi stage length. Table 5-3 shows the intermediate/long haul aircraft for a 2000 n mi stage length. All cost estimates are for the year 1985 in 1973 dollars except for the fuel element. As shown in the tables, two study fuel price levels were used in developing total DOC estimates: \$79/m<sup>3</sup> (30¢/gal) and \$158/m<sup>3</sup> (60¢/gal). The year 1985 was selected for these tables as that was the availability designated for the CL-1320-13 propfan. Also, considering current trends in the industry, 1980 is not a realistic introductory year for the new near-term class of vehicles.

The DC-8, 727 and 737 estimates in these tables do not include any basic airplane depreciation as they will all have been fully depreciated by 1985. Actual 1973 depreciation elements for these aircraft are, however, included in table 2-3. Also, some analysts prefer trip costs over block-hour costs as comparative data, therefore, tables 5-2 and 5-3 include block times for the selected distances to enable conversion to trip costs.

TABLE 5-2

TOTAL DIRECT OPERATING COSTS  
SHORT/MEDIUM HAUL AIRCRAFTFor Year 1965 in 1973 \$  
(except fuel price as noted)

		500 Naut. Mile Stage Length		
		\$/Block-Hour		Block-Hours
		\$79/m <sup>3</sup> (30c/gal)	\$158/m <sup>3</sup> (60c/gal)	
Baseline A/C	737-200	670	940	1.43
	727-100	750	1110	1.43
	727-200	780	1160	1.44
Aerodynamic Modifications	737-200	660	910	1.48
	727-100	736	1080	1.43
	727-200	760	1130	1.44
Derivative A/C	727-300	1190	1600	1.45
	L-1011 Short Body	1590	2200	1.34
	DC-10-10D	1380	1860	1.43
New Near-Term A/C	200-1500-30	1360	1770	1.38
	200-1500-60	1350	1730	1.40
	200-1500-Min	1300	1660	1.46
Prop-Fan	CL-1320-13	1200	1500	1.48



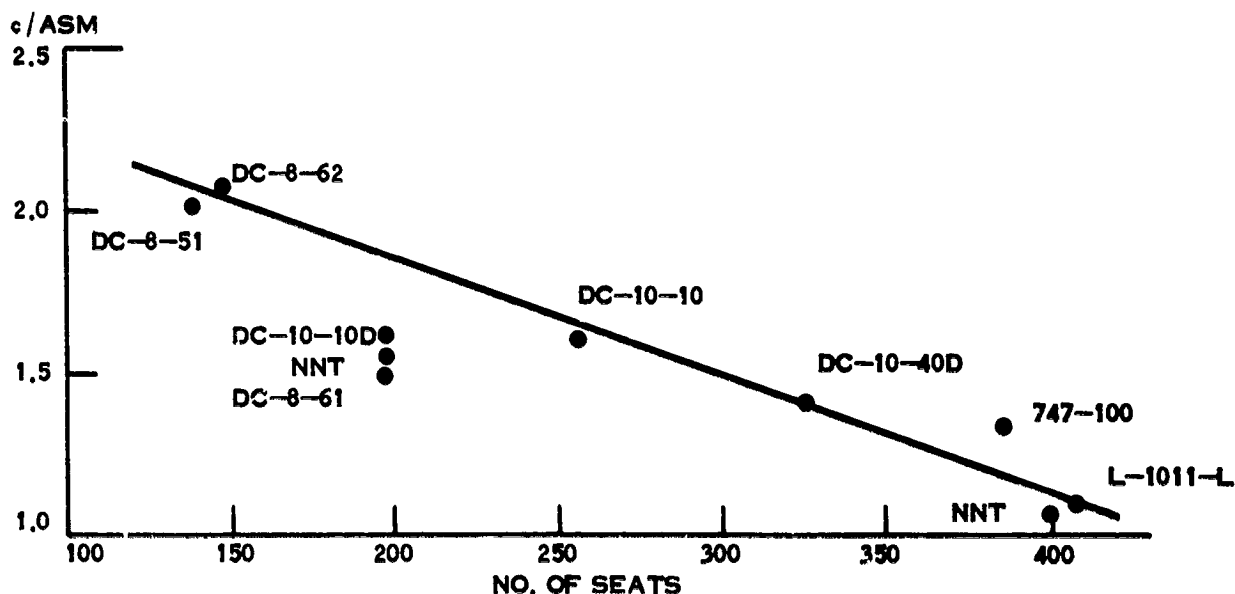
TABLE 5-3

TOTAL DIRECT OPERATING COSTS  
INTERMEDIATE/LONG HAUL AIRCRAFTFor Year 1985 in 1973 \$  
(except fuel price as noted)

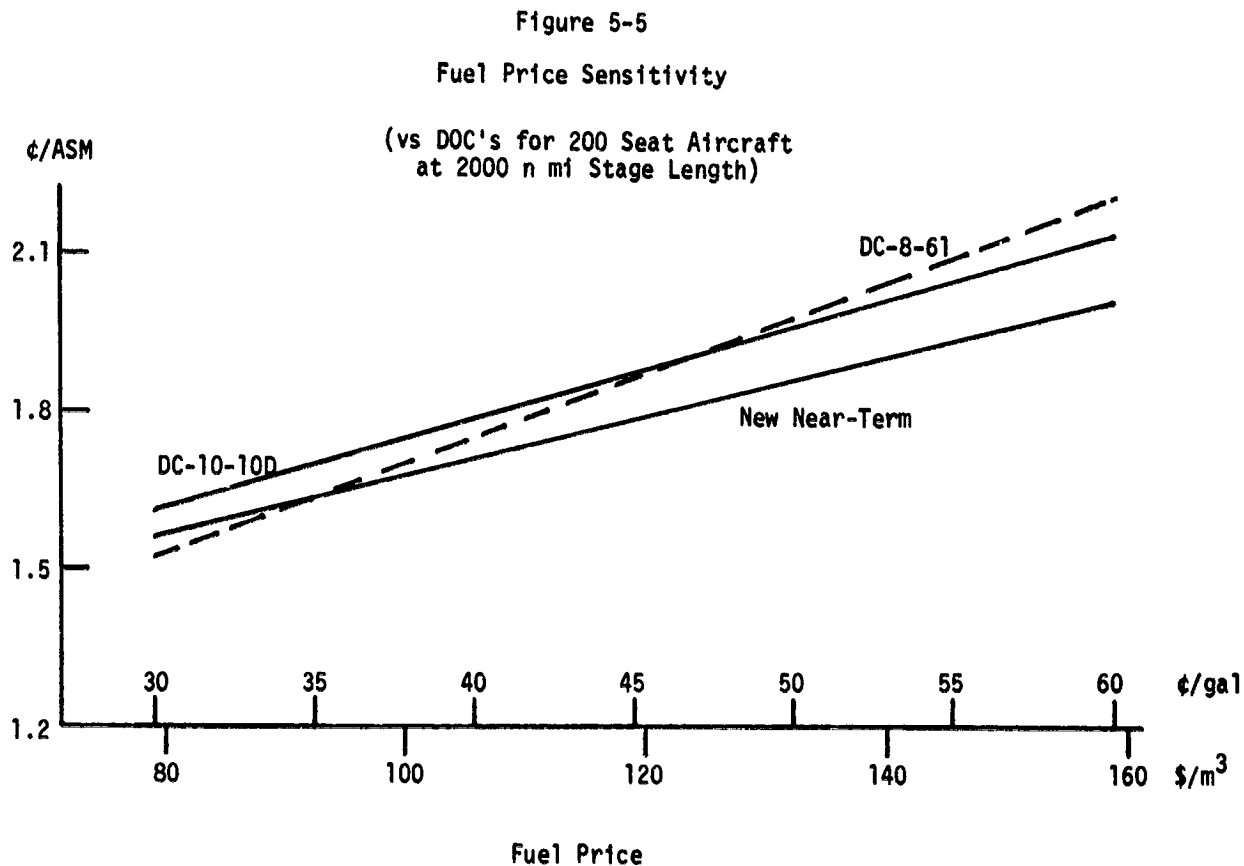
		2000 Naut Mile Stage Length		
		\$/Block-Hour		Block- Hours
		\$79/m <sup>3</sup> (30c/gal)	\$158/m <sup>3</sup> (60c/gal)	
Baseline Aircraft	DC-8-20	1070	1680	4.7
	DC-8-51/-52	970	1480	4.7
	DC-8-61	1030	1600	4.7
	DC-8-62	960	1450	4.7
	DC-10-10	1760	2370	4.7
	747-100	2110	3040	4.7
Aerodynamic Modifications	DC-8-20	1060	1640	4.7
	DC-8-51/-52	960	1440	4.7
	DC-8-61	1000	1540	4.7
	DC-8-62	950	1420	4.7
	DC-10-10	1740	2180	4.7
	747-100	2080	2970	4.7
Aerodynamic + Engine Modifications	DC-8-20	1070	1600	4.7
	DC-8-51/-52	1020	1680	4.7
	DC-8-61	1130	1950	4.7
	DC-8-62	1010	1930	4.7
Derivative Aircraft	L-1011 Long Body	1970	2720	4.6
	DC-10-10D	1390	1840	4.6
	DC-10-40D	2040	2710	4.5
New Near-Term Aircraft	200-3000-30	1340	1750	4.6
	200-3000-60	1300	1680	4.8
	200-3000-Min	1310	1670	5.0
	400-3000-30	1880	2580	4.6
	400-3000-60	1800	2440	4.8
	400-3000-Min	1830	2460	5.0

Figure 5-4 graphically compares DOC's per available seat mile in a format similar to fuel efficiency figure 5-1. For this presentation, a depreciation element was included in the DC-8 costs. Similar to fuel efficiency, the DOC's on a cents per seat-mile basis generally decrease as the state-of-the-art advances and as vehicle capacity increases. The DC-8-61 is an exception as its DOC's are quite low. At \$79/m<sup>3</sup> (30¢/gal) fuel its DOC's are lower than the advanced 200-seat airplanes. This is due primarily to (1) a lower DC-8-61 depreciation element and (2) a higher projected maintenance cost level for the advanced aircraft with their high bypass engines.

Figure 5-4  
DIRECT OPERATING COSTS  
2000 N. MI. STAGE LENGTH  
\$79/m<sup>3</sup> (30¢/gal) Fuel

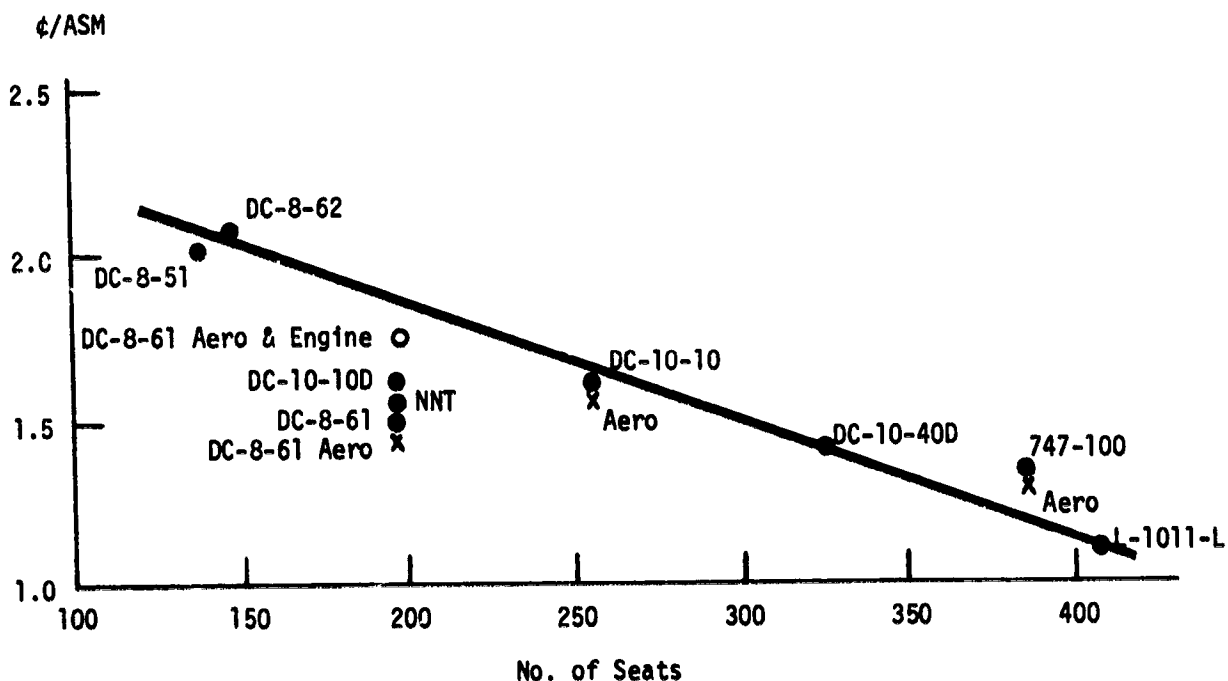


As fuel price increases, however, the advanced aircraft become more cost effective than the DC-8-61. Figure 5-5 illustrates DOC sensitivity to fuel price. With all other DOC elements held constant, the DC-8-61 becomes more costly on a ¢/ASM basis than (1) the new near-term airplane when fuel price reaches approximately 36¢ and (2) the DC-10-10D when the price reaches approximately 47¢.



Retrofit modification DOC's for some of the intermediate/long haul aircraft are illustrated in figure 5-6 and generally reflect the tabular trends shown in table 5-3. The aerodynamic modifications offer the potential for slightly reduced DOC's as fuel cost savings more than offset the retrofit cost. For the aerodynamic + engine modifications, the investment element (4.8 million in 1973 dollars) drives the DOC's upward substantially despite up to 15% savings in fuel.

Figure 5-6  
DIRECT OPERATING COSTS - RETROFIT  
2000 N. MI. STAGE LENGTH  
\$79/m<sup>3</sup> (30¢/gal) Fuel



The airplane total DOC's presented in the preceding discussion were derived by estimating costs for each of the DOC elements such as maintenance costs, flight crew, etc. The paragraphs that follow describe the development of costs for the various DOC elements for each of the fuel conserving options.

### Maintenance

For the aerodynamic and aerodynamic plus engine retrofit options, the section 2 data served as the cost base. The aerodynamic modifications are not perceived to measurably affect maintenance costs, therefore section 2 rates were used directly. For the aero + engine modifications a slight increase was assumed for the new engine (JT8D-209). For the 727-300, maintenance cost estimates from United's files were used. Maintenance cost baselines for the Douglas and Lockheed derivative aircraft, the new near-term aircraft and the turboprop were supplied by Douglas and Lockheed. Their rates were then adjusted using airline factors as described in section 4.

Maintenance cost estimates for new airplanes are often developed using formulas that include airplane weight as an independent variable. Therefore, the maintenance cost estimate may be low for the CL-1320-13 turboprop which would incorporate active controls and substantial composite material usage as weight reducing state-of-the-art advances. We believe that these technologies will produce higher maintenance costs than would be encountered with a comparable conventional aluminum transport (ref 4).

### Flight Crew

The flight crew cost analysis was conducted in the same manner as the maintenance cost study with the turboprop airplane an exception. For the retrofit airplanes section 2 flight crew cost rates were used. These rates were used as the mission schedules would be essentially unchanged from current operations and differences training associated with the engine modifications would have a negligible effect when total life cycle costs are considered.

The Douglas and Lockheed derivative aircraft and the new near-term aircraft flight crew rates were developed by applying block time adjustment factors, per section 4, to manufacturer developed rates. The turboprop was handled differently, however. The passenger capacity and range criteria for the turboprop is the same as the 200-passenger, 1500 n mi new near-term airplane and, therefore, its airline mission assignment would be the same. We considered, notwithstanding TOGW differences, that differences in flight crew pay between such vehicles would be doubtful. Accordingly, the turboprop crew cost rates were assigned the values derived for the 200-passenger, 1500 n mi, DOC30 near-term vehicle.

### Flight Equipment Depreciation

United uses the straight-line depreciation method for CAB reporting. Therefore, depreciation expense per airplane per year for new aircraft is the same for all years in the study (disregarding capital improvements during the life of the asset). A sixteen year term was used for all new aircraft studied. Purchase price estimates provided by Douglas and Lockheed were increased 2.2% to allow for custom airline features or changes (ref 4). A spares allowance of 15% of flyaway cost was included in the investment base.

The depreciation schedules selected for the retrofit options were (1) for aero modifications, the longer of three years or the remaining depreciable life of each particular airplane and (2) for aero + engine modifications, the longer of five years or the remaining depreciable life. These three/five year periods were combined with the depreciation end dates shown in table 2-6 and depreciation expenses were computed for each study year.

### Registry Tax and Hull Insurance

Registry tax expense is a constant annual expense that is handled as discussed in section 2. Hull insurance, however, declines with time as it generally is related to current book value. Therefore, a projected book value was computed for each airplane type at each of the study years 1980, 1985 and 1990. Annual hull insurance expense per airplane was then estimated at 0.5% of book value for the new airplanes and 0.4% of book value for existing aircraft.

### CABIN SPACE REQUIREMENTS

The history of powered flight has been fraught with the problem of not having as much vehicle interior space as was desirable. Present day transports certainly appear to be expansive; however, it is still necessary to consider certain space requirements. The proposed derivative and new near-term designs were not developed in sufficient detail to allow in-depth analysis of the cabin interior layouts. In the absence of such specific analysis, a general discussion of cabin space requirements is provided.

Cabin Storage.-- The allocation of storage space is determined as much by the size and seating capacity of the aircraft as the length of haul and, in some cases, is limited by the initial design of the manufacturer. Generally there have not been definite guidelines for storage allocation on our aircraft.

Flight crew, cabin crew, coat rack and overhead storage are more related to aircraft size and/or seating capacity than length of haul. The following guidelines would be desirable for these areas:



TABLE 5-4  
CABIN SPACE ON CURRENT FLEETS

Aircraft	Coat Rack Hanger Bar - cm (in)/psgr	Overhead Storage - m <sup>3</sup> (ft <sup>3</sup> )/psgr	Galley - m <sup>2</sup> (ft <sup>2</sup> )/psgr		Lavatory Ratio - psgr/Lavatory	
			F	Y	F	Y
DC-8-52 Charter	2.1 ( .84)	.031 (1.1)	-	.040 ( .43)	-	51
DC-8-61 Charter	1.3 ( .53)	.034 (1.2)	-	.042 ( .45)	-	45
DC-8-62 Charter	1.0 ( .40)	.031 (1.1)	-	.034 ( .37)	-	43
DC-8-51/-52	2.6 (1.02)	.037 (1.3)	.120 (1.29)	.031 ( .33)	11	54
DC-8-61	1.8 ( .71)	.040 (1.4)	.129 (1.39)	.040 ( .43)	14	52
DC-8-62	1.2 ( .49)	.037 (1.3)	.145 (1.56)	.051 ( .55)	20	41
DC-10-10	2.1 ( .81)	.034 (1.2)	-	.132 (1.42)*	21	40
747-100	2.2 ( .88)	.017 ( .6)	.562 (6.05)	.072 ( .78)	10	39
727-100	1.9 ( .73)	.040 (1.4)	-	.033 ( .35)*	12	43
727-200	1.4 ( .56)	.037 (1.3)	.222 (2.39)	.028 ( .30)	14	56
737-200	1.6 ( .63)	**	.208 (2.24)	.030 ( .32)	10	85

\* One galley serves both cabins.

\*\* 737 does not have enclosed bins; the overhead stowage area is .186 m<sup>2</sup> (2.0 ft<sup>2</sup>)/passenger.



## SECTION 6

### AIRLINE REALISM

A characteristic present in successful long range planning processes, particularly those relating to projections of capital equipment expenditures, is that recommendations are not developed in the isolation of theoretical study. A fleet planning function incorporates the application of a number of factors for projecting long term equipment requirements. The aircraft purchase decisions of non-nationalized airlines are based on operational requirements in combination with an assessment of the ability of an aircraft to make a profit for stockholders. The major variables in an economic evaluation of aircraft are market demand, yield, cost, return on investment and capital availability. Together, these economic factors form the "realisms" which airline managements consider before purchase of aircraft. The ability to forecast these variables reasonably well for the investment life of an aircraft is critical to the success of a purchase decision.

#### MARKET DEMAND

Market demand forecasting for air travel at United uses several nationally distributed GNP forecasting services, such as General Electric Mapcast and Chase Econometrics. These GNP forecasts contain data on income level, general education level of the population, amount of leisure time and other travel related economic variables. These variables are correlated and used to predict total demand for air travel. Applying market share projections to this total demand, individual market forecasts are developed to which fleet requirement projections can be fitted. The assumptions associated with this projected economic environment are shown in table 6-1.

We forecast that the domestic economy will experience a real growth of about three percent per year. Inflationary pressure is reflected in the forecast current GNP growth of about nine and a half percent per year over the period between the base year of 1973 and the end forecast year of 1990. We project personal consumption expenditures to reflect this inflationary environment and to reflect a constant share of GNP throughout the projection period.

The price of domestic air transportation expressed in terms of real yield has declined when compared to general price trends. A historical comparison of current and real yields for U.S. domestic trunk scheduled air traffic is shown below along with projections for the years 1980, 1985 and 1990.

<u>Year</u>	<u>Historical Yield</u>	
	<u>Current</u>	<u>Real*</u>
1950	6.38¢/RPM	7.22¢/RPM
1955	6.13	6.69
1960	6.92	7.16
1965	6.71	6.82
1970	6.64	5.94
1973	7.35	6.02

	<u>Projected Yield</u>	
	<u>Current</u>	<u>Real*</u>
1980	12.2 ¢/RPM	5.4 ¢/RPM
1985	16.9	5.5
1990	22.7	5.5

\* Real Yield based on Consumer Price Index;  
1967 = 100.

We expect present air transportation prices in real dollars to drop slightly until 1980 due to increased productivity from higher load factors and increased equipment utilization and then level off for the decade of the 1980's. Based on this economic scenario, we project normal traffic growth to remain above the growth expected in employment as well as real GNP.

Table 6-2 shows United's market projections for the total domestic scheduled and non-scheduled certified carriers for three fuel scenarios. The most severe growth constraint is the fuel rationing situation which would lead to very high load factors (the ratio of revenue passenger miles to available seat miles) and, if sustained, would become intolerable from a service point of view.

The 1973 passenger load factor for the industry was 52%, generating a net profit of about \$175 million and a return on industry investment of roughly 5%. Over the forecast period we project industry growth in lift to be below growth in traffic, resulting in higher load factors for the industry. Due to seasonal, weekly and time of day peaking in demand, we expect industry annual load factors to level off at a peak of about 62%. This is shown in table 6-2's ratio of RPM's to ASM's. As will be demonstrated later, such a load factor may not be enough to allow an adequate return on investment at forecasted yields and costs.

Average scheduled trip length has grown slightly every year; a reflection of both the trend toward higher traffic growth in long-haul markets and relative unprofitability of short-haul flying. The projection of passengers and revenue passenger miles expresses an expectation of a continual growth trend in average segment length.

TABLE 6-1  
PROJECTION OF ECONOMIC VARIABLES

	1973 Actual Amount	Projected					
		1980		1985		1990	
		Amount	Growth Rate 1974-1980	Amount	Growth Rate 1981-1985	Amount	Growth Rate 1986-1990
Civilian Employment (M11)	84.4	95	1.7%	101	1.2%	107	1.2%
Real GNP (B11 1973 \$)	1306	1580	2.8%	1832	3.0%	2113	3.0%
Current GNP (B11)	1306	2580	10.2%	4015	9.3%	6100	8.7%
Current Personal Consumption Expenditures (B11)	809	1644	10.7%	2570	9.3%	3900	8.7%
Federal Reserve Board Production Index (1967 = 100)	125.6	151.5	2.7%	177	3.2%	206	3.1%

TABLE 6-2  
DOMESTIC INDUSTRY\* MARKET FORECAST  
LIFT AND LOAD

	1973 Actual	1980	Average Annual Increase 1973-1980	1985	Average Annual Increase 1980-1985	1990	Average Annual % 1985-1990
<u>Overall Growth</u>							
RPM's (B11)	112.9	162	5.3%	213	5.6%	254	4.4%
ASM's (B11)	216.5	277	3.6	346	4.5	421	4.0
Psgrs (M11)	180.0	242	4.3	294	4.0	346	3.3
<u>Fuel Rationing (1974 Level)</u>							
RPM's (B11)	N/A	162	5.3%	188	3.0%	188	--
ASM's (B11)	N/A	221	0.4	221	--	221	--
Psgrs (M11)	N/A	203	1.7	213	0.9	199	-1.4%
<u>Double Fuel Price</u>							
RPM's (B11)	N/A	148	3.9%	193	5.5%	240	4.5%
ASM's (B11)	N/A	252	2.2	313	4.4	383	4.1
Psgrs (M11)	N/A	220	2.9	266	3.8	314	3.4

N/A = Not Applicable

\* Total scheduled and non-scheduled operations of the trunk, regional and supplemental carriers.

### Fuel Rationing

In the event that fuel availability for air transportation should be limited to the 1974 level referenced in table 6-2, we would expect normal market growth to be slowed down beyond 1980 and totally stopped in terms of RPM's beyond 1985. Total lift in terms of ASM's would remain constant at 1974 levels except for those increases available from changing first class/coach seat mix, reducing seat pitch and adding one seat to each row in wide-body aircraft. Given the available fleet mix and available lift, capacity is capable of growing a total of about nine percent from an actual 203 billion seat miles generated in 1974 to a level of 221 billion seat miles by 1980, beyond which further growth without further fuel usage would have to be obtained with new technology aircraft not now available.

Fuel rationing at 1974 levels would result in progressively larger portions of the public being unable to obtain air transportation at their choice of departure date and time and would eventually result in substantial rejected demand. Short of total change in present flight reservation and scheduling methods, it would be impossible to attain system load factors of 85% as reflected in the 1985 and 1990 load factors shown in table 6-2 for the "Fuel Rationing" alternative.

The projection of number of passengers carried under fuel allocations shows a drop in the total accommodated between 1985 and 1990 (table 6-2). We believe that given such an environment, national policy as well as air transport industry economics would cause scheduling of aircraft which would provide the highest demand satisfaction as well as the best travel time return for limited fuel resources. Consequently, we project minimization of short-haul flying since short-haul traffic could be accommodated by surface transport modes without substantial time loss. Airline fuel use can then be shifted to longer stage lengths where accommodation of growing long-haul markets is of substantial value.

### Market Elasticity - Double Fuel Price

A projection of demand was made on the assumption that an increase in fuel price from \$91.40/m<sup>3</sup> (34.6¢ per gallon) to \$158/m<sup>3</sup> (60¢ per gallon) took place. This increase would result in a 15% increase in airline total expenses and presumably would be passed through directly in the form of higher fares.

We do not believe that conclusive evidence has been presented to reach agreement on air travel demand price elasticity. To avoid non-conclusive discussions on the issue of price elasticity, we have used the -0.7 elasticity coefficient established by the CAB in the Domestic Passenger Fare Investigation of 1970-1974. With this elasticity coefficient, a one-time (direct pass through) lowering of the market forecast of 9.3% takes place, which has been reflected in the projection for RPM's for the "Double Fuel Price" alternative in table 6-2. The lift to accommodate this traffic has been scaled in our projection to reflect the same load factors as in the normal overall growth case. The average stage length assumption was held the same in both the

normal overall growth case and the increased fuel price case resulting in the numbers shown in table 6-2.

Our macro industry forecast is intended to cover the domestic scheduled and non-scheduled operations of the Trunk, Regional, and Supplemental Carriers, a universe usually referred to as "50 State Operations". The methodology used to forecast traffic losses as a result of fuel price increases is shown in tables 6-3 and 6-4 and is extrapolated to cover the total forecast as well as the trunk forecast in the two tables. We have tried to express in the three forecast scenarios some measure of market vulnerability to exogenous forces. The "best estimate" projection of normal growth does reflect the concept that constantly high growth rates of the magnitude found in the sixties will not occur again. If growth rates in reality should prove measurably different from those shown in table 6-2, the reduced energy conservation measure findings of this study would still be valid, but would be applicable at an earlier or later date than we have shown depending on whether traffic growth was more or less rapid than forecast.

#### Trip Purpose and Length of Haul Forecasts

Tables 6-5 and 6-6 present passenger and passenger mile distribution by length of haul and table 6-7 presents distribution by trip purpose and length of haul. United has a continuing program of inflight passenger surveys through which statistics on subjects such as trip purpose, fare basis and frequency of travel are gathered for selected segments on a quarterly basis. We have used trends from this data base to construct trip purpose projections. We have also used the CAB's Origin and Destination Surveys for the years 1970 through 1974 and, on the basis of these findings and our own data, we projected the distribution of industry passengers by length of haul shown in table 6-5. The same data sources are the basis of the distribution to RPM projections in table 6-6.

As a percent of the total air travel market, we forecast short-haul (0-519 n mi) to continue its trend of declining importance, although in absolute terms this market will still show some increase over the study period. The largest increases are expected in the 520 to 865 n mi medium-haul segments. Because of slightly different measuring cells, segment lengths in the passenger and passenger mile distribution vary a little from the segment length of the trip purpose projection.

Because of United's size and the pattern of its segment coverage, we have used United's data as the source for the forecasts in table 6-7. As a result, the business/non-business split shown in this table is an extrapolation to the industry from United data. We do project a shift in share toward more non-business traffic. Today's traffic is divided approximately even between business and non-business when we include the non-scheduled (charter) portion of traffic in the non-business category. Tables 6-8 and 6-9 show the base data from the United surveys used in the table 6-6 forecast.

TABLE 6-3

DOMESTIC TRUNK INDUSTRY TRAFFIC FORECASTS -  
ELASTICITY COEFFICIENT IMPACT DEVELOPMENT

Year	UAL Base Forecasts		Extraction of UAL Elasticity Coefficient Impact		Addition of CAB Elasticity Coefficient Impact	
	(1)	(2)	(3)	(4)	(5)	(6)
	Real Yield Forecast (B/RPM)	Trunk Industry Traffic Forecast (Billions of RPM's)	UAL Elasticity Impact Projections Included in Column (2) Data (Billions of RPM's)	Trunk Industry Traffic Forecast at Constant Real Yield of 5.24/RPM (Billions of RPM's)	Real Yield Change as a Percent of 1975 Real Yield (%)	-0.7 CAB Elasticity Coefficient Impact on Constant Yield Forecast (%)
1975	5.24	103.6570	--	103.6570	100.00	100.00
1976	5.12	110.7471	.7586	109.9885	97.71	101.63
1977	5.13	116.2933	.3034	115.9899	99.05	100.67
1978	5.17	124.8473	.4551	124.3922	98.66	100.95
1979	5.16	131.3496	.5310	130.8186	98.47	101.09
1980	5.18	136.6979	.3793	136.3186	98.85	100.61
1981	5.20	141.5423	.2276	141.3147	99.24	100.54
1982	5.27	145.1302	-.2276	145.3578	100.57	99.61
1983	5.33	150.1215	-.6063	150.7283	101.72	98.81
						103.6570
						111.7813
						116.7670
						125.6739
						132.2445
						137.4226
						142.0775
						144.7909
						148.5346

## Methodology:

Column (1) = UAL real yield forecast.

Column (2) = UAL trunk industry traffic forecast which includes UAL price elasticity impact projections.

Column (3) = The magnitude of UAL elasticity impact projections included in the column (2) forecasts. The elasticity coefficient used by UAL is different from the -0.7 coefficient established by the CAB.

Column (4) = Column (2) - column (3) = Removal of UAL elasticity impact projection thus giving traffic forecasts based on a constant yield of 5.24c/RPM (1975).

Column (5) = [Column (1) + 5.24] x 100 = Yield change from the 1975 real yield expressed as a percentage.

Column (6) = Elasticity impact using the CAB -0.7 elasticity coefficient, expressed as a percentage, and computed as follows:

$$\log T = K - B / (\log P)$$

where:  $T$  = elasticity impact (%)  
 $K$  = 3.4 (a constant)  
 $B$  = -0.7 (CAB elasticity coefficient)  
 $P$  = Price change (%) per column (5)

Column (7) = [Column (4) x column (6)] + 100 = Traffic forecast based on UAL yield projections and the CAB elasticity coefficient.

$$\text{example: For 1975 } \log T = 3.4 - 0.7 / 100.57$$

$$\log T = 3.4 - 0.7 / 1.9899$$

$$\log T = 3.4 - 1.3523 = 2.00767$$

$$T = 101.63$$

TABLE 6-4  
IMPACT ON DOMESTIC TRUNK TRAFFIC OF INCREASED FARES  
(CAB Elasticity Factor of -0.7)

Development of Traffic Forecasts Based on 15% Higher Fares				Computation of Traffic Loss due to Elasticity Effect of Higher Fares	
(1) Real Yield Forecast for \$158/m <sup>3</sup> (60¢/gal) Fuel Scenario (c/RPM)	(2) Real Yield Change as a Percent of 1975 Real Yield (%)	(3) -0.7 CAB Elasticity Coefficient Impact on Constant Yield Forecast (%)	(4) Traffic Forecast @ Double Fuel Price Yields and CAB Elasticity (Billions of RPM's)	(5) Traffic Forecast @ Current Fuel Price Projections and CAB Elasticity (Billions of RPM's)	(6) Traffic Loss due to 15% Increase in Fares (Billions of RPM's)
Year					
1975	5.24	100.00	103.6570	103.6570	--
1976	5.89	112.40	101.3434	111.7923	10.4489
1977	5.97	113.93	105.8640	116.7670	10.9030
1978	5.95	113.55	113.8064	125.5739	11.7675
1979	5.93	113.17	119.9606	132.2445	12.2839
1980	5.96	113.74	124.5679	137.4228	12.8549
1981	5.98	114.12	128.7660	142.0778	13.3118
1982	6.06	115.65	131.2872	144.7764	13.4892
1983	6.13	116.98	135.0526	148.9346	13.8820

Methodology:

Column (1) = [Table 6-3 column (1) x 1.15] for years 1976 and subsequent. Assumes that approximate doubling of fuel price produces a 15% increase in airline total expenses that passes through as a 15% increase in fares.

Column (2) = [Column (1) ÷ 5.24] x 100 = Yield change from the 1975 real yield expressed as a percentage.

Column (3) = Elasticity impact using the CAB -0.7 elasticity coefficient and the relationship  $\log T = 3.4 - .7 \log P$  (re table 6-3).

Column (4) = [Table 6-3 column (4) x column (3)] ÷ 100 = Traffic forecast based on column (1) yield assumptions and CAB elasticity coefficient.

Column (5) = Table 6-3 column (7) repeated.

Column (6) = Column (5) - column (4) = Traffic loss due to elasticity effect of a 15% fare increase accompanying an approximate doubling of fuel price. These traffic losses expressed as percentages are all about 9.3% as  $\log T = 3.4 - .7 \log 115 = 1.957511$  and  $\text{antilog } 1.957511 = 90.68$  and  $100\% - 90.68\% = 9.32\%$ .

TABLE 6-5  
INDUSTRY PERCENT PASSENGER DISTRIBUTION  
BY LENGTH OF HAUL

Stage Length - Nautical Miles	Actual					Projection		
	1970	1971	1972	1973	1974	1980	1985	1990
0 - 519	49.26%	47.88%	47.18%	47.42%	47.55%	45%	44%	41%
520 - 865	20.29	21.15	21.62	21.71	21.69	24	26	29
866 - 1384	15.91	16.68	17.19	16.93	16.71	17	17	17
1385 - 1730	5.23	5.17	5.03	4.99	5.08	5	5	5
1731 - 2249	7.46	7.33	7.18	7.09	7.07	7	6	6
2250 +	<u>1.85</u>	<u>1.79</u>	<u>1.80</u>	<u>1.86</u>	<u>1.90</u>	<u>2</u>	<u>2</u>	<u>2</u>
	<u>100.00%</u>	<u>100.00%</u>	<u>100.00%</u>	<u>100.00%</u>	<u>100.00%</u>	<u>100%</u>	<u>100%</u>	<u>100%</u>

TABLE 6-6  
INDUSTRY PERCENT PASSENGER MILES DISTRIBUTION  
BY LENGTH OF HAUL

Stage Length - Nautical Miles	Actual					Projection		
	1970	1971	1972	1973	1974	1980	1985	1990
0 - 519	18.80%	18.53%	18.28%	18.40%	18.41%	17.8%	17.2%	16.6%
520 - 865	18.98	19.62	20.10	20.28	20.26	21.7	23.5	25.2
866 - 1384	22.95	23.70	24.28	24.01	23.67	23.8	24.0	24.2
1385 - 1730	11.08	10.83	10.50	10.46	10.60	10.3	9.9	9.5
1731 - 2249	20.69	20.12	19.66	19.50	19.32	18.3	16.9	15.6
2250 +	<u>7.50</u>	<u>7.20</u>	<u>7.18</u>	<u>7.36</u>	<u>7.74</u>	<u>8.1</u>	<u>8.5</u>	<u>8.9</u>
	<u>100.00%</u>	<u>100.00%</u>	<u>100.00%</u>	<u>100.00%</u>	<u>100.00%</u>	<u>100.0%</u>	<u>100.0%</u>	<u>100.0%</u>



TABLE 6-7  
MARKET FORECAST  
INDUSTRY PASSENGERS  
BY TRIP PURPOSE AND LENGTH OF HAUL

	1980		1985		1990	
	Business	Non-Business	Business	Non-Business	Business	Non-Business
Total	<u>47.5%</u>	<u>52.5%</u>	<u>45.5%</u>	<u>54.5%</u>	<u>44.5%</u>	<u>55.5%</u>
Distributed as follows: (Nautical Miles)						
0 - 434	29%	2%	27%	17%	26%	15%
435 - 1302	48	50	50	52	53	56
1303 - 1737	13	17	13	17	13	17
1738 - 2171	6	9	6	9	5	7
2172 +	<u>4</u>	<u>5</u>	<u>4</u>	<u>5</u>	<u>3</u>	<u>5</u>
	<u>100%</u>	<u>100%</u>	<u>100%</u>	<u>100%</u>	<u>100%</u>	<u>100%</u>

TABLE 6-8  
MAJOR SURVEY RESULTS 1970 TO 1975  
SCHEDULED TRAFFIC ONLY

		1970				1971				1972			
		<u>FEB</u>	<u>MAY</u>	<u>AUG</u>	<u>NOV</u>	<u>FEB</u>	<u>MAY</u>	<u>AUG</u>	<u>NOV</u>	<u>FEB</u>	<u>MAY</u>	<u>AUG</u>	<u>NOV</u>
Business	%	56.2	53.8	33.1	56.4	51.9	50.2	33.0	55.0	54.2	49.2	35.2	53.6
Non-Business	%	43.8	46.2	66.9	43.6	48.1	49.8	67.0	45.0	45.8	50.8	64.8	46.4

		1973				1974				1975			
		<u>FEB</u>	<u>MAY</u>	<u>AUG</u>	<u>NOV</u>	<u>FEB</u>	<u>MAY</u>	<u>AUG</u>	<u>NOV</u>	<u>FEB</u>	<u>MAY</u>	<u>AUG</u>	<u>NOV</u>
Business	%	56.2	51.8	36.3	56.3	56.2	55.9	38.2	60.1	54.9	52.2	35.7	55.9
Non-Business	%	43.8	48.2	63.7	43.7	43.8	44.1	61.8	39.9	45.1	47.8	64.3	44.1

TABLE 6-9  
SAMPLE OF INFLIGHT SURVEY CELLS

Main Purpose of Trip	Total	Length of Haul - Naut Miles						2171 & More
		0 - 433	434 - 867	868 - 1302	1303 - 1736	1737 - 2170		
Company Business or Professional Practice	4454	1223	1815	375	668	241	132	45.7%
Government Related Business	487	122	152	61	65	76	11	3.8
Attend Convention, Trade Fair, Etc.	744	142	280	75	180	45	22	7.6
Military Duty	104	20	36	13	28	7	-	-
Business (Net)	5789	1507	2283	524	941	369	165	57.1%
Accompany Family Member on Business Trip	244	63	75	23	54	22	7	2.4%
Visit Friends for Pleasure	594	98	247	86	112	35	16	5.5
Visit Relatives for Pleasure	1786	314	718	208	378	109	59	20.4
Sightseeing, Visiting Resort	946	94	366	143	246	77	20	6.9
Personal Emergency Such as Illness	569	104	254	57	124	20	10	3.5
Personal Affairs	546	115	245	65	89	20	12	4.2
Military Pass or Leave	179	32	78	9	47	13	-	-
Other Purposes	17	3	9	2	3	-	-	-
Pleasure (Net)	4881	823	1992	593	1053	296	124	42.9%
Analyzed Respondents	10670	2330	4275	1117	1994	665	289	100.0%
No Answer	66	13	29	7	11	4	2	-

## UNITED AIRLINES SYSTEM FORECAST

Given the assumption of a continuation of a competitive air transportation system, we believe the best rationale for study purposes is to project the same market share for United in the forecast period as exists today. We are aware that regulatory and economic forces probably would not allow a status quo to prevail for another fifteen years, but we cannot predict what events would happen that could change the relative size of each carrier. We therefore show for United in table 6-10 a system forecast extracted from the industry macro forecast (table 6-2) based on our current market share.

TABLE 6-10  
MARKET FORECAST  
UNITED SYSTEM LIFT AND LOAD

	1980	Average Annual Change 1973-1980	1985	Average Annual Change 1980-1985	1990	Average Annual Change 1985-1990
RPM's (B11)	36	+5.2%	48	+5.8%	58	+4.0%
ASM's (B11)	61	+4.3	78	+5.2	91	+3.1
Psgs (M11)	40	+3.6	49	+4.2	57	+3.1

Air transportation is a maturing industry. We are expecting growth rates to decline over the study period covered and to level out slightly above the growth rate for the United States economy. This is reflected both in the industry and in United's forecast. We also expect cost pressures to drive load factors well above the 58 percent level which was initially discussed as a parameter for the study.

As a management philosophy and an operating policy, United does not believe in passenger load factors which are so high as to result in substantial rejected demand. Through monitoring of loads and analysis of capacity and demand, we know that on a particular flight on a specific type of equipment some rejected demand exists above a sixty percent load factor level. This rejected demand becomes significant in the seventy to seventy-five percent range. Whether this rejected demand from a given flight is satisfied on other flights in the approximate same timeframe is difficult to measure. If a total transportation system such as scheduled air carrier service would experience load factors in the seventy percent range, substantial demand would exist which would not otherwise be carried.

## COST AND YIELD ESCALATION

United has experienced dramatic fuel price increases since 1973 and expects fuel prices to continue to climb at about 10% per year through the rest of this decade. Beyond 1980, increased availability of alternate energy sources to other fuel users will lessen upward pressures on petroleum prices. Other costs, driven primarily by increasing wages, are forecasted to increase at rates in excess of nine percent between now and 1980, but are projected to level off at about the long term inflationary rate beyond 1980. Cost escalation projections are found in table 6-11.

Historically, the air transportation industry has experienced productivity gains which have more than offset cost inflation. Most of these productivity gains have been related to the increased efficiency of new aircraft designs, with the turnover of fleets in the 1960's from piston to jet aircraft by far the most important single factor. In the 1940's and 1950's substantial increases in piston aircraft size and efficiency offset the modest inflationary pressure of those decades. The introduction of wide-body aircraft improved productivity in the early 1970's until markets suitable for wide-body capacity became saturated with lift. In 1975 growing load factors caused a significant productivity increase and some additional gain potential still exists through further load factor increase, use of higher seating densities and higher aircraft utilization rates. These potential gains are far less than needed to offset an 8% annual cost inflation rate and airline industry earnings are already severely depressed due to the extremely heavy fuel price driven inflation of 1973-1975.

Yield increases of 7-8% will be necessary over the next four years to offset forecast cost escalation rates even with substantial productivity gains from higher load factors, seating density and aircraft utilization. Table 6-12 shows projections of average annual yield increases of 6.4% over the study years. We have added actual historical data to provide perspective. The average annual increase between 1970 and 1975 of 4.8% indicates that the forecast increase may be difficult to achieve.

A comparison of the projected cost and yield escalation shows cost increases continuing to outdistance yield growth over the study years. Productivity increases, both from introduction of more efficient aircraft and more effective use of current aircraft, are a necessity if the airlines are to raise the capital required to re-equip.

TABLE 6-11  
UNITED COST ESCALATION FORECAST

	Actual		Projected Average Annual		
	1974/1973	1975/1974	1975-1980	1980-1985	1985-1990
Fuel	+68 %	+22 %	+9.8%	+6.1%	+6.0%
Other	+10.2%	+ 9.3%	+9.4%	+6.5%	+6.0%
Composite	+17.5%	+12.2%	+9.6%	+6.4%	+6.0%

TABLE 6-12  
UNITED YIELD ESCALATION FORECAST

	1970	1971	1972	1973	1974	1975	Average Annual
Actual Rate of Change	+4.1%	+5.7%	+1.4%	+4.8%	+12.9%	+0.6%	+4.8%

Forecast Rate of Change	1976 - 1980	1981 - 1985	1986 - 1990	
	+7.1%/yr.	+6.5%/yr.	+5.5%/yr.	
				+6.4%

## RETURN ON INVESTMENT

Airlines must compete with both private enterprises and government for capital. United applies a hurdle rate concept for investment decisions as a tool for obtaining a desired capital structure. Investments that meet or exceed the hurdle rate are expected to insure financial strength and make it possible to continue to obtain financing. United's hurdle rate of 15% is predicated on our desire to obtain a 50/50 debt/equity ratio, the need to meet an after tax payback requirement of 10% to 11% and our desire to maintain sufficient coverage for necessary non-financial advantage projects.

The major elements in United's 15% hurdle rate are as follows:

1. Cost of capital is a weighted composite of the cost of debt and the cost of equity; United's current debt/equity goal is the achievement of a 50/50 ratio.
2. Cost of debt is estimated to range between 10% and 11% based on current and projected yields for long term debt of comparable risk grade, specifically Standard and Poor's BBB rating.
3. Cost of equity is judgmentally estimated at 15%-18% based on a risk premium of between 5% and 7% applied to the cost of debt.
4. Estimated cost of capital, using the 50/50 target debt/equity ratio, ranges from a minimum of 10.0% to a maximum of 11.75%. This is based on the after tax rate approach which recognizes that the effective cost of debt is reduced by income taxes avoided.
5. To compensate for non-financial advantage projects, a coverage factor must be applied to the cost of capital to establish the hurdle rate. Based on the 1974, 1975 and 1976 Capital Plans, coverage for the 26% average of non-financial advantage projects dollar requests which can be anticipated requires the addition of a 1.35 coverage factor ( $1 + .74$ ) to the cost of capital. Examples of non-financial advantage projects include floor venting modifications, the installation of proximity warning systems and other safety related actions.
6. Adjusting for coverage, the hurdle rate calculated based on the above rates should be not less than 13.5% and not more than 15.9%.

Collectively, the airline industry is not in a position with its historical earnings record to secure money today for new equipment purchases. We do not believe that the financial markets are going to be persuaded over the remainder of the 70's and into the 80's to lend the necessary funds to re-equip the airlines unless a convincingly different profit record can be developed.

## SECTION 7

### ECONOMIC IMPLICATIONS

In section 6 we developed the general economic environment in which United expects reduced energy consumption aircraft to operate. In this section we will develop the general methodology and expound on economic implications in the fleet planning exercise used in the study.

Because of the existence of profit criteria for long term fleet replacement, an adequate rate of return on aircraft investment capital is the primary input to fleet planning evaluations. Four of the five factors which affect a discounted cash flow rate of return on investment are operating cost, passenger and cargo volume, passenger and cargo yield, and aircraft utilization. The yield-cost relationship is not equal throughout all flown distances, and fixed costs can be spread over a larger base as flying is increased. As flown segment lengths and aircraft utilization increase, the payload necessary to produce an adequate rate of return is lowered.

Investment size is the fifth factor and there are several ways of stating the value of an aircraft including book value, original cost, fair market value, opportunity cost and replacement cost. In an inflationary economic environment, replacement cost will result in the most accurate application (e.g., investment cost per seat has nearly doubled over the past four years). Currently, the operating fleet is priced and allocated in service according to its historical investment base, while growth and replacement aircraft consideration is accomplished on a replacement price investment base. In this study we have employed the replacement value used by United on out-of-production aircraft and the current purchase price on in-production or new study aircraft in 1973 dollar terms.

### FUTURE AIRCRAFT NEEDS MODEL

The fleet planning process used in the study employs a fleet selection model referred to as the Future Aircraft Needs (FAN) model. This model combines operating costs, yields, utilization and investment costs by fleet type with segment market size and, on the basis of this match, assigns the best equipment mix from among the alternatives to carry traffic over each segment. The model incorporates an economic screen which enables United to evaluate a broad spectrum of aircraft (on hand as well as new candidates) against a desired rate of return. The model output is a segment coverage schedule for United's system. The economic screen, screen adjustment, investment criteria, segment market forecast and FAN methodology are discussed further below.

## Economic Screen

Economic screens are tools used to measure the relative profitability of scheduling different aircraft types in the long range fleet planning and scheduling process.

Inputs to economic screen calculations are: (1) the economic assumptions of yield and cost elements and their escalation; (2) investment life and tax treatment; (3) operating costs; (4) aircraft operation assumptions of payload range, seating capacity and mix; and (5) utilization rate. Table 7-1 portrays an example of the assumptions used in building the screens for this study. A discounted cash flow methodology is employed to measure the potential success of the investment under evaluation. The discounted cash flow approach adjusts revenue and expense cash flows to reflect the time value of money. Although the assumed life of an aircraft investment can cover any number of years, United normally assumes a sixteen year life for analysis of new aircraft plus two to three years of aircraft prepayments.

In an investment analysis of the cash flow type used here, we have elected to use tax depreciation rather than book depreciation. A seven year tax depreciation period consisting of four years of double declining and three years of straight line depreciation has been employed. Table 7-2 shows one of the sample inputs for the aircraft tested. The top line on this table identifies the major equipment types and the second line (labeled CAPCTY) shows the total number of seats assumed to be on the aircraft. The next two lines define the assumed first class and coach mix as a fraction of total lift. In this study this ratio was held constant on each candidate aircraft at 10 percent first class and 90 percent coach. The analysis program calculates the average fare from this mix. Lines five, six and seven define aircraft utilization parameters and together with minimum and maximum length of haul, as shown on lines eight and nine, reflect the mission which the aircraft performs. Utilization is expressed in terms of daily block hours and length of haul is expressed in nautical miles. The line labeled TAXI shows the average time spent per departure in a decimal fraction of an hour to move from the gate to the beginning of the takeoff roll and from the end of the landing roll to the gate. Lines 11 through 18 are cost statements in dollars per occurrence as follows:

- Insurance - The cost per aircraft day for hull insurance and aircraft registration fees.
- Ground Fuel - The average fuel cost per departure for taxiing the aircraft from and to the blocks.
- Flight Fuel - The average cost per flown hour for the fuel used to climb, cruise and descend.
- Block Hour Cost - The average cost per block hour for flight crew and cabin crew on the payroll including salary and payroll associated costs such as fringe benefits, payroll taxes and direct payroll administration.



Departure Cost - The average cost per departure for landing fees, aircraft servicing, aircraft controlling and ground facility maintenance and depreciation.

Flown Hour Cost - Stabilized long term maintenance cost and maintenance burden per flown hour.

Audio and Movie - The average cost for maintaining entertainment equipment and payment for use of tapes and film, but not the initial installation of equipment.

The numbers on the two lines labeled INTER (Y-intercept) and REG COF (regression coefficient) are analytical inputs used in establishing the number of departures per day and are calculated on the basis of a regression analysis of flown speed and taxi time, considering the aircraft mission range and daily utilization rates. The bottom line gives total cost per aircraft including spares and spare engines. The numbers are expressed in thousands of dollars and are based on the 1973 price, either actual or estimated, per the study ground rules.

The output from this discounted cash flow return on investment analysis is in terms of the number of passengers required to meet the return on investment hurdle rate and is shown in tables 7-3, 7-4, 7-5 and 7-6. The fleet economic screens reflect the passenger criteria for the individual aircraft in the total fleet. The required passengers would change with changes in utilization as well as capacity of any given candidate. Shown at the top of each column are the assumed block hour utilization and the seating capacity of the aircraft. The required passenger loads shown consider the revenue generated by the average experienced cargo load.

#### Economic Screen Adjustment

For most equipment types, the economic screen would require more than a 100% load factor in segments under 174 n mi to meet the 15% hurdle rate. The major economic benefit to a carrier from short-haul traffic is to feed medium- to long-haul flights. Therefore, to reflect the economic value of connecting traffic, the screen is adjusted by shifting passenger equivalents needed to meet the hurdle rate from short-haul segments to long-haul segments keeping the same overall return on investment for the full screen, but reducing short-haul load factors to achievable levels. In short, long-haul segments are adjusted to subsidize short-haul segments, reflecting the reality of the fare structure and CAB service requirements. Tables 7-3 through 7-6 reflect such adjustments.

The end product of the screen adjustment process is an economic screen which requires average day passenger loads that translate to achievable load factors for the same equipment type over all segment lengths. As an adjustment base we used the departure and flight statistics found in United's 1976 planning

data for our 1980 schedule. The adjustment procedure used in this study is as follows:

- Sort all average daily departures into appropriate mileage blocks in 86 n mi increments from shortest to longest haul.
- Multiply the number of departures in each mileage block by the average fare for that length of haul to get a "departure revenue" value for each length of haul.
- Multiply this number by the total passengers required for all aircraft in the fleet in the appropriate mileage block to meet the 15% hurdle rate.
- The sum total of this multiplication becomes the "control" number in the adjustment process.

Example only:

Control Number Calculation

Naut Miles	Daily Departures	Average Fare	Departure Revenue Value	15% ROI Fleet Mix Passengers	Control Number
86	218.3	15.20	3318	4600	15,262,800
174	174.1	24.40	4248	1590	6,754,320
261	174.3	31.50	5490	1248	6,851,520
347	140.8	39.20	5519	1056	5,828,064
⋮	⋮	⋮	⋮	⋮	⋮
2258	14.2	159.20	2261	595	1,345,295
2345	-	166.05	-	591	-

Adjustment Control Number = 77,282,831

- The adjustment is an iterative process shifting numbers of passengers from the low mileage increments to the other increments so that the control number associated with adjusted load factors is as close as possible to the original (unadjusted) number.

Example continued:

Naut Miles	Unadjusted		Adjusted	
	Control Number	Load Factor	Control Number	Load Factor
86	15,262,800	316%	4,347,907	90%
174	6,754,320	110	5,566,579	90
261	6,851,520	86	7,194,096	90
347	5,828,064	73	6,830,314	85
⋮	⋮	⋮	⋮	⋮
2258	1,345,295	52	1,678,382	65
2345	-	52	-	65
	77,282,831	70%	77,203,797	76%

The adjusted screen is used because it is appropriate when dealing with a systemwide set of statistics. An alternative would be to keep data by segment, subtracting passengers from the long haul as they are added to the short haul. Such a procedure becomes virtually impossible with an airline serving 92 airports, with potentially  $(92)^2$ -92 city pairs and multiple routings between most of these city pairs.

The major weakness in the adjusting procedure is that it credits short-haul segments with little actual feed value to an airline's long-haul routes with the same feed value as segments with above average feed value. While this weakness affects the use of adjusted screens in the aircraft scheduling process, since shorter haul fleets are generally purchased to serve multiple markets, this error is not significant in its fleet planning use.

### Investment Criteria

The fleet economic screen used in the FAN model utilizes discounted cash flow. Consequently, the investment hurdle rate target is measured over the entire life of the aircraft type evaluated. As a result, the accounting return on investment could vary substantially from year to year because, in any discounted cash flow approach, the early years of cash flow have a much larger effect on rate of return than later years.

The FAN model uses equipment replacement cost as the value of aircraft in service. Three types of investment cost could be used for this type of analysis: market value, book value and replacement value. Used market value and book value tend to understate the investment required to replace aircraft as used market values do not take into account the cost of converting an aircraft to a carrier configuration, and book values are as a rule significantly understated due to inflation.

### Market Forecast by Segment

This forecast is made by United field operating divisions on a by flight, by month basis. The 1980 forecast is provided in appendix B and the 1985 and 1990 forecasts follow the general growth pattern stipulated in the overall marco forecast. The by flight forecast is condensed to an average day, one direction forecast with the opposite directions assumed to be the same level of traffic. In FAN model use, this results in the further assumptions that aircraft allocated in one direction are assumed to also be of the same type on the return trip. This approach not only reduces the segment coverage development time and computational expenses, but facilitates conversion of segment coverage schedules taken from the FAN model output into full, timed schedules. In this study we have avoided using peak period forecasts, but if necessary or desired, they could be employed. System growth rates were used from a forecast base year (1980) forward. There are no individual segment growth rates available to adjust the forecast file.

TABLE 7-1  
ECONOMIC SCREEN INPUT EXAMPLE

INPUT ELEMENT		VALUE				
Analysis Period (including 3 prepayment years)		18 years				
Target ROI		15%				
Escalation Factors:		1980	1985	1990		
Yield	(1976 = 100)	1.3157	1.7873	2.4031		
Costs	(1976 = 100)	1.4429	1.8838	2.5119		
Investment	(1974 = 100)	1.4116	N/A	N/A		
Aircraft Prepayment:		16% of flyaway price				
	18th year	12%	"	"	"	
	17th year	72%	"	"	"	
	16th year					
Publicity & Advertising Expense		1.55% of revenue				
Liability Insurance & Agency Commissions		\$.00417 per RPM				
Passenger Handling Expense		\$8.53 per psgr boarded				
Passenger Meals: Less than 1/2 hr flight		\$1.25 per psgr boarded				
More than 5 hr flight		\$6.13 per psgr boarded				
Average		\$4.00 per psgr boarded				
General & Administrative Expense		5.70% of total costs (excl leases and G&A)				
Yield: 1976 assumption, from		¢ per RPM				
43.4 n mi in		21.88	18.42	16.12	14.76	13.62
43.4 n mi increments		12.95	13.53	11.95	11.52	11.17
		10.73	10.42	10.04	9.79	9.45
		9.30	9.10	8.96	8.77	8.65
		8.57	8.50	8.39	8.30	8.23
		8.18	8.06	8.01	7.95	7.85
		7.77	7.69	7.58	7.48	7.47
		7.47	7.45	7.43	7.42	

TABLE 7-2

ECONOMIC SCREEN INPUT  
OPERATING ASSUMPTIONS

(All cost assumptions are in 1976 \$ except investment which is in 1974 \$)

EQUIPMENT		737-100			727-100			727-200			DC-8-20			DC-8-50/727-300			DC-8-61			DC-10-101			DC-10-400		
CAPCTY -	no. of seats	95	98	126	129	129	129	129	129	129	129	156	184	256	349	200	407	200	407	200	407	200	407		
FIRST MIX - %		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10			
COACH MIX - %		90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90			
AVG DAILY UTIL - blk-hrs/day		7	8	8	9	8	8	8	8	8	8	9	9	10	11	5	5	5	5	5	5	5			
MIN DAILY UTIL - blk-hrs/day		6	7	7	8	7	7	7	7	7	7	8	8	9	10	10	10	10	10	10	10	10			
MAX DAILY UTIL - blk-hrs/day		8	9	9	10	9	9	9	9	9	9	10	10	11	13	10	10	10	10	10	10	10			
MIN LGTH OF HAUL - n mi		43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43			
MAX LGTH OF HAUL - n mi		868	2300	1867	2779	2779	2779	2779	2779	2779	2779	1997	3647	3474	5515	1607	2100	1607	2100	1607	2100	1607			
TAXI - hrs		21	23	23	23	23	23	23	23	23	23	23	23	24	29	23	23	23	23	23	23	23			
INSURANCE - \$/apl-day		28	33	47	34	34	34	34	34	34	34	113	71	155	231	156	221	156	221	156	221	156			
GRND FUEL - \$/departure		26	41	41	47	47	47	47	47	47	47	53	53	704	1041	561	750	561	750	561	750	561			
FLT FUEL - \$/flight-hr		279	407	442	668	668	668	668	668	668	668	496	639	726	860	584	841	584	841	584	841	584			
BLK HR COST - \$/blk-hr		382	402	431	476	476	476	476	476	476	476	483	511	968	1261	758	1261	758	1261	758	1261	758			
DEPRT COST - \$/departure		318	392	410	517	517	517	517	517	517	517	468	622	968	1261	758	1261	758	1261	758	1261	758			
FLN HR COST - \$/flt-hr		208	246	251	316	316	316	316	316	316	316	295	310	533	810	562	810	562	810	562	810	562			
AUDIO - \$/apl-day		--	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12			
MOVIE - \$/apl-day		--	--	--	60	60	60	60	60	60	60	60	60	60	60	--	--	--	--	--	--	--			
INTER		51470	83329	67684	73047	73047	73047	73047	73047	73047	73047	83329	76701	126100	136000	28334	49745	28334	49745	28334	49745	28334			
REG COF		433960	507000	493055	505554	505554	505554	505554	505554	505554	505554	507080	502947	536960	548060	468485	471420	468485	471420	468485	471420	468485			
INVEST - \$/apl (000's)		7160	7616	10626	10327	10327	10327	10327	10327	10327	10327	16123	14963	24307	34179	22473	31673	22473	31673	22473	31673	22473			

EQUIPMENT	New Near-Term Aircraft															
	DC-10-10D	CL-1320	200-1500-30		200-1500-60		200-3000-30		200-3000-60		400-3000-30		400-3000-60		400-3000 -Min	
CAPCTY - no. of seats	199	200	200	200	200	200	200	200	200	200	200	400	400	400	400	
FIRST MIX - %	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	
COACH MIX - %	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	
AVG DAILY UTIL - blk-hrs/day	9	8	8	8	8	8	9	9	9	9	9	9	9	9	9	
MIN DAILY UTIL - blk-hrs/day	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
MAX DAILY UTIL - blk-hrs/day	10	9	9	9	9	9	10	10	10	10	10	10	10	10	10	
MIN LGTH OF HAUL - n mi	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	
MAX LGTH OF HAUL - n mi	2171	1259	1259	1259	1259	1259	2518	2518	2518	2518	2518	2518	2518	2518	2518	
TAXI - hrs	23	23	23	23	23	23	33	33	33	33	33	33	33	33	33	
INSURANCE - \$/apl-day	146	121	121	121	136	141	143	143	147	147	225	218	218	225	243	
GRND FUEL - \$/departure	215	116	167	344	305	171	366	702	337	366	687	687	687	399	454	
FLT FUEL - \$/flight-hr	405	242	336	620	580	384	702	577	678	702	577	577	577	1255	1271	
BLK HR COST - \$/blk-hr	586	592	592	592	592	592	592	592	592	592	592	592	592	796	796	
DEPRT COST - \$/departure	785	765	771	771	779	779	779	779	779	779	779	779	779	1276	1286	
FLN HR COST - \$/flt-hr	472	443	503	505	518	458	458	458	471	471	471	574	574	560	590	
AUDIO - \$/apl-day	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	
MOVIE - \$/apl-day	60	--	--	--	--	60	60	60	60	60	60	60	60	60	60	
INTER	49707	95537	34543	29557	33588	85000	66944	66944	57865	57865	69497	65226	65226	47115	47115	
REG COF	471600	463350	455744	438354	427441	474342	448559	448559	433564	433564	457674	446306	446306	431539	431539	
INVEST - \$/apl (000's)	21269	19737	20336	23440	21540	23186	23586	23586	24222	24222	35851	36792	36792	38935	38935	

TABLE 7-3

**FLEET ADJUSTED ECONOMIC SCREEN  
ALTERNATE I - 1980  
(Aerodynamic Modifications Included)**

Number of Passengers Required  
to Meet 15% ROI

Aircraft Type	737 -200	727 -100	727 -200	727 -300	DC-8 Std	DC-8 -61	DC-10 -10	747 -100
Seating Capacity	95	98	126	156	129	184	256	369
Blk-hrs/Day	7	8	8	9	9	10	10	12
Stage Length - Naut. Miles								
86	90	92	111	135	129	148	239	324
174	90	92	111	135	129	148	237	324
261	90	92	111	135	129	146	236	324
347	89	92	111	135	128	142	215	287
434	88	92	111	134	126	141	210	286
521	85	92	111	134	125	139	206	286
608	85	92	110	132	125	138	202	269
695	85	92	109	131	123	136	200	265
782		91	108	129	123	134	199	258
864		90	104	122	116	127	186	238
955		82	97	116	109	120	173	234
1042		77	91	108	101	112	159	207
1129		77	91	108	101	112	159	207
1216		77	91	108	101	112		
1303		77	91	108		112		
1389		77	91	108				
1476		77	91	108				
1563		77	91	108				
1650		77	91	108				
1737		77	91	108				
1824								
1910								
1997								
2084					↓	↓	↓	↓
2171								
2258					101	112	159	207
2345					101	112	159	207

TABLE 7-4

FLEET ADJUSTED ECONOMIC SCREEN  
ALTERNATE II - 1980  
(Aerodynamic Modifications Included)

Number of Passengers Required  
to Meet 15% ROI

Aircraft Type	737 -200	727 -100	727 -200	DC-10 -10D	DC-8 Std	DC-8 -61	DC-10 -10	747 -100
Seating Capacity	95	98	126	199	129	184	256	369
Blk-hrs/Day	7	8	8	9	9	10	10	12
Stage Length - Naut. Miles								
86	90	92	111	192	129	146	235	318
174	90	92	111	192	129	146	234	308
261	90	92	111	188	128	145	233	308
347	90	92	111	182	126	141	212	280
434	90	92	111	180	125	139	208	273
521	90	92	110	178	124	138	204	268
608	90	92	109	176	124	137	195	263
695	90	92	108	174	122	135	195	259
782		92	108	174	122	135	195	257
864		88	103	163	116	127	185	239
955		88	103	163	116	127	185	239
1042		82	103	163	116	127	183	237
1129		82	97	152	109	120	171	221
1216		82	97	152	109	120	171	221
1303		82	97	152	109	120	171	221
1389		76	90	142	101	111	159	205
1476		76	90	142	101	111	159	205
1563		76	90		101			205
1650		76	90					
1737		76	90					
1824								
1910								
1997								
2084								
2171				142				
2258					101	111	159	205
2345					101	111	159	205

TABLE 7-5

FLEET ADJUSTED ECONOMIC SCREEN  
 ALTERNATE III - 1980  
 (Aerodynamic Modifications Included)

Number of Passengers Required  
 to Meet 15% ROI

Aircraft Type	737 -200	727 -100	727 -200	L-1011 Short	L-1011 Long	DC-8 Std	DC-8 -61	DC-10 -40D
Seating Capacity	95	98	126	200	407	129	184	327
Blk-hrs/Day	7	8	8	8	8	9	10	10
Stage Length - Naut. Miles								
86	90	92	111	195	305	129	147	310
174	90	92	111	195	304	129	146	310
261	90	92	111	194	304	127	143	310
347	90	92	111	192	285	124	139	299
434	90	92	111	192	283	124	138	299
521	90	92	110	192	283	124	138	291
608	90	92	109	192	283	124	138	288
695	90	92	108	192	283	124	138	284
782		92	108	189	272	119	132	272
864		88	107	189	271	119	132	268
955		88	105	187	267	118	130	265
1042		88	105	187	263	116	128	259
1129		87	103	186	260	115	127	255
1216		86	102	184	257	113	125	251
1303		85	100	181	253	112	123	248
1389		79	94	169	236	104	115	232
1476		79	94	169	236	104	115	232
1563		79	94	169	236	104	115	232
1650		76	87	157	219	97	107	215
1737		76	87	157	219	97	107	215
1824					219	97	107	215
1910						97	107	212
1997						97	107	211
2084						97	107	210
2171						97	107	210
2258						97	107	210
2345						97	107	210



TABLE 7-6  
FLEET ADJUSTED ECONOMIC SCREEN  
1985  
(Aerodynamic Modifications Included)

Number of Passengers Required  
to Meet 15% ROI

Aircraft Type	727 -200	CL- 1320	DC-10 -10D (L-1011 Short)	NNT 200- 3000	NNT 400- 3000	DC-8 -61	DC-10 -10	747 -100
Seating Capacity	126	200	199	200	400	184	256	369
Blk-hrs/Day	7	8	8	9	10	9	10	11
Stage Length - Naut. Miles								
86	113	185	185	190	311	151	234	323
174	113	185	185	190	311	151	232	317
261	113	185	185	190	311	149	232	316
347	113	180	184	189	293	146	215	292
434	113	180	183	188	291	142	207	278
521	113	178	183	188	282	142	205	277
608	113	177	183	188	282	142	202	271
695	113	175	183	188	281	140	199	267
782	109	165	172	177	258	133	187	250
864	108	165	172	177	258	133	187	249
955	108	165	172	176	258	133	187	248
1042	106	165	172	175	258	133	186	247
1129	102	165	162	166	241	125	173	230
1216	102	165	162	166	241	125	173	230
1303	101		160	166	241	125	173	230
1389	96		152	156	227	118	163	217
1476	96		152	156	227	118	163	217
1563	96		152		227			
1650	96		152					
1737	96		152					
1824			152					
1910			152					
1997			152					
2084			152					
2171			152	156				
2258				156		118	163	217
2345				156	227	118	163	217

### FAN Methodology

To make aircraft selections from many viable fleet candidates, the economic side of the model is matched with the market side. The steps in United's fleet selection process are:

- The adjusted economic screen, which includes fifteen percent investment return, is furnished as a table in the economic program.
- The screen is sorted to create all possible fleet combinations which will carry a given number of passengers a given length of haul. The inner and outer limits of the length of haul are 43 and 2388 nautical miles, reflecting United's shortest and longest flying with the exceptions of several inland to Hawaiian points. This file is reduced to reflect minimum load factor and maximum frequency for any given market size.
- The screen is then matched with the segmentized market (passenger) forecast and a first selection is made to determine optimal fleet mix as well as the number of departures for each segment in the forecast.
- A summary of the type and number of aircraft is produced along with the associated fleet operating data.

The model is designed to maximize number of departures and minimize load factors (by market segment) while meeting the investment hurdle rate. The initial output of the aircraft combinations contained in the economic screen (some 60,000 possibilities for United) from the lowest length of haul and smallest number of passengers to the highest is really a tool to determine an ideal fleet. If a carrier were to start without any aircraft on hand and had to match its "market" with aircraft need, this sorted, initial screen would indicate what an ideal fleet should look like.

### FAN Market Adjustment

The purpose of the FAN model is to produce a fleet combination which, given economic and market input, will meet investment hurdle rate requirements. Initial model output will consequently not fly any segment in the forecast which, even with minimum coverage, does not meet hurdle rate requirements. These relatively unprofitable segments have to be forced into solution if they are to be flown.

Segments under forty-three nautical miles cannot be economically flown, even assuming feed value to downline segments, and are therefore not used for justifying purchase of new equipment. Segments in this range are primarily flown for schedule construction purposes, such as aircraft or crew positioning. Scheduling incongruencies will exist due to the inability of the model

on its own to allocate aircraft to segments which are unprofitable in their own right but are necessary to complete a schedule pattern. Such deficiencies are remedied through an iterative process which forces such flying.

The final schedule selections which result from these iterations may possibly, but not necessarily, result in economics falling below a system investment hurdle rate. Although some uneconomical flying is forced into solution, output tends to exceed the investment hurdle rate because the model will have chosen equipment that meets or exceeds investment hurdle rate economics. For example, if three 737's at a 434 n mi segment require 240 passengers (84% load factor) and the market forecast is 230 passengers, the model will choose the alternative prior to three 737's which may only require 210 passengers and result in a higher load factor.

#### Segment Coverage Notes

The model-produced segment coverage schedule is not an operable schedule. It is not timed or initially balanced and does not consider market requirements for "prime time" departures. Equipment utilization in the model schedule does, however, allow enough aircraft to schedule the same percentage of prime time departures as is present in today's schedule patterns. For example, an aircraft can be flown for approximately fourteen hours per day if utilized over a twenty-four hour day. Assuming only a seven to ten hour average utilization it is also assumed that the equipment will be flown only during normal hours thus covering prime time departures.

The FAN model develops operational segment coverage only, and does not re-flow passengers when a segment is deleted due to the lack of sufficient passengers. The traffic forecast used by the model is based on a specific traffic flow pattern developed from the actual schedules. It could be argued that since the traffic forecast portion of the model is geared to a particular schedule, and that since segment traffic forecasts do not change as the FAN model adds new equipment and reduces or increases departures, the model should re-flow traffic to produce the best results. The model is designed to give a "best solution" given multiple scenarios on fleet types, and it can best serve this purpose without becoming involved in the complex question of traffic flow. On previous occasions United has, through a task force approach, developed a "clean slate" schedule and found that 80% of the schedule was virtually identical to the previous schedule, without significant traffic and re-flowing. The results from the model show a high correlation with current and future schedules normally developed outside the model.

One of the great advantages of the FAN model is that it shows the impact on United's system of operating new aircraft with the current fleet. A candidate aircraft may appear promising alone, but if flown in consort with existing equipment performing the same or a similar mission, the proposal may not fit the existing fleet. With a given set of fleet assumptions the model result will show the best alternative when taken in the context of existing fleets. Used as an analytical tool by an analyst familiar with fleet planning

and scheduling, the FAN model makes a valuable contribution to fleet purchase, fleet retirement and fleet scheduling decisions.

#### Load Factors Versus Return on Investment Criteria

An early approach in the study was an attempt to produce a test result based on a sixty percent overall load factor (originally fifty-eight percent) and a fifteen percent return on investment. Given the cost and yield forecast assumptions used, we could not generate a fifteen percent return on investment at a sixty percent load factor on the fleet alternatives available.

Consequently, for purposes of the study, we assumed return on investment to be of greater importance than load factor and selected schedules with about seventy-five percent load factors in order to achieve a fifteen percent investment return. In table 7-7 we have shown the impact of the 1980 fleet solution if it had to meet the sixty percent load factor criteria. Thirty-two additional units (compared to the 76% load factor solution) would have to be scheduled with the result that return on investment would fall substantially below fifteen percent. The sixty percent load factor and a fifteen percent ROI would probably be more achievable if the under 261 n mi segments were eliminated. As shown in the sixty percent load factor column, 40 DC-10's were used because United estimates that its DC-10 fleet should reach that size by 1980. If aircraft that equaled the average size of the aircraft in the 76 percent load factor alternative were to be added to achieve a 60 percent load factor, total units would increase by approximately fifty instead of thirty-two.

It should again be emphasized that United does not advocate system load factors in the area of seventy-six percent as load factors that high are relatively unrealistic. We previously mentioned that with such load factors, a considerable part of the flying public would be inconvenienced in respect to choice of departure and route of flying.

TABLE 7-7  
60 VS 76 ANNUAL LOAD FACTOR  
1980 COMPARISON

Aircraft Type	Number of Units	
	60 Load Factor	76 Load Factor
B-737	53	53
B-727-100	60	60
B-727-200	1	27
DC-8 STD	24	13
DC-8-61/62	12	23
DC-10-100	4	6
DC-10-10	40	20
747	14	12
	276	244

## AIRCRAFT CONSIDERED

The array of fuel saving aircraft designs was briefly described from an engineering/operational point of view in section 4. Table 7-8 lists the economic load results for new derivative candidate aircraft used in the study.

All aircraft designs were originally planned for introduction in 1980. We later decided to divide the designs into two groups, one to be introduced in 1980 and the other in 1985. Since it would be unrealistic to test both derivative aircraft and new aircraft designs as being introduced into service in the same time frame, we allowed derivative designs, as well as the aerodynamic modifications on the existing fleet, to be in the 1980 fleet alternatives. Advanced turboprop and the new near-term aircraft were placed in the 1985 fleet selections. No new aircraft were introduced in the 1990 fleet.

Table 7-9 portrays the various candidate aircraft as they were input to United's fleet. In the 1985 scenario only the new near-term aircraft designed for \$79/m<sup>3</sup> (30 ¢/gal) fuel were selected. In an economic testing prior to the fleet planning selection both the \$158 (60¢) fuel designs and the minimum fuel designs were found to be economically inferior to the \$79 (30¢) design.

Aircraft used in the fleet selection model were:

### Existing Fleet Candidates

- Boeing 737-200: A short range, two engine aircraft introduced in United's fleet in the mid-sixties. It is flown in a two-class 95 seat configuration.
- Boeing 727-100: A short to medium range three engine aircraft of considerable flexibility. United flies it in a two-class 98 seat configuration.
- Boeing 727-200: A stretched version of the 727-100 with 126 seats. United's model is equipped with JT8D-7 engines and has less range than the 727-100. New versions of the aircraft have the same range as the 727-100.
- DC-8-20/-51/-52: A 129 seat, two-class aircraft used in medium-to long-haul flying with four engines of either the JT4 type (DC-8-20) or the JT3D (DC-8-51/-52) type. In this study all DC-8-20/-51/-52 aircraft were assumed to have the higher fuel burn of the DC-8-20 for fleet selection, except for the re-engining test where the -20 and -51/-52 fuel economics were separately considered.

- DC-8-61: The stretched version of the standard DC-8 with 184 seats in a two-class configuration. This aircraft is designed for medium to long haul segments and is equipped with four JT3D fan engines. (United also operates nine long range DC-8-62 aircraft which were not considered in fleet selection model, as they are all planned for charter service.)
- DC-10-10: A three engine medium- to long-haul wide-body aircraft. In this phase of the study its capacity was assumed to be 256 seats (9-across) although United currently flies with 242 seats in a two-class, 8-across configuration.
- Boeing 747-100: United operates 18 of this four engine medium to long haul aircraft in a two-class 342 seat (plus eight salable lounge seats) version. In this phase of the study we assumed a 369 seat (10-across) installation as being the most likely 1980-1990 seating configuration.

#### New Fleet Candidates

- Aerodynamic modifications on all existing aircraft resulting in operating cost estimates previously exhibited in section 5.
- Aerodynamic plus engine modifications on the DC-8-20, DC-8-51/-52 and DC-8-61.
- Derivative and new near-term aircraft as described in section 4.
- An advanced turboprop also described briefly in section 4.

Both the L-1011 Long Body and the 727-300 showed good short-haul economic performance. However, the L-1011 Long Body proved too large for the forecast market needs and United, after a recent thorough economic and engineering examination, did not select the 727-300 as a fleet replacement candidate.

TABLE 7-8  
DERIVATIVE AIRCRAFT COMPARISON

PASSENGER REQUIRED FOR A 15% ROI  
(ASSUME 1980 AVAILABILITY)

	727-300		L-1011 SHORT		DC-10-100		DC-10-400		L-1011 LONG	
	Psgs.	Load Factor	Psgs.	Load Factor	Psgs.	Load Factor	Psgs.	Load Factor	Psgs.	Load Factor
Capacity	156	--	200	--	199	--	327	--	407	--
Naut. Miles										
87	470	301%	654	327%	675	339%	1203	368%	1059	260%
174	166	106	237	119	234	118	404	124	369	91
261	130	83	187	94	179	90	319	98	298	73
434	104	67	153	77	141	71	239	73	224	55
868	97	62	145	73	128	64	204	62	206	51
1303	93	60	141	71	122	61	193	59	197	48
1737	93	60	N/A		122	61	193	59	197	48
2171	N/A		N/A		119	60	184	56	N/A	

TABLE 7-9  
FLEET ALTERNATIVES

I	1980		1985	1990
	II	III		
737-200 Fixed	737-200 Fixed	737-200 Fixed	727-200 Open	727-200 Fixed
727-100 Fixed	727-100 Fixed	727-100 Fixed	DC-8-61 Fixed	DC-8-61 Fixed
727-200 Open	727-200 Open	727-200 Fixed	DC-10-100 (L-1011 Short) Open	DC-10-100 (L-1011 Short) Open
Std DC-8 Fixed	Std DC-8 Fixed	Std DC-8 Fixed	CL-1320 Open	CL-1320 Open
727-300 Open	DC-10-100 (L-1011 Short) Open	L-1011 Short Open	NNT 200-3000 Open	NNT 200-3000 Open
DC-8-61 Fixed	DC-8-61 Fixed	DC-8-61 Fixed	DC-10-10 Open	DC-10-10 Open
DC-10-10 Open	DC-10-10 Open	L-1011 Long Open	747-100 Open	747-100 Open
747-100 Open	747-100 Open	DC-10-400 Open	NNT 400-3000 Open	NNT 400-3000 Open

Fixed = Unavailable for new purchase.

Open = Available for new purchase.

## SECTION 8

### ECONOMIC FINDINGS

#### FLEET ALTERNATIVES

In the fleet selection study we tested four fleet combinations. Three of these combinations were run with the same 1980 market and the fourth was run with the 1985 market. Table 7-9 shows the three 1980 alternatives and the 1985 candidate. From a practical point of view it is not likely that an airline would totally replace a large fleet type in a short period of time. We allowed the aircraft currently on hand to be in solution in a reasonable quantity for the 1980 market. In the 1985 and 1990 markets we removed those aircraft which at the moment appear to be the most likely candidates to be replaced -- 737-200, 727-100, and DC-8-20/-51/-52. We assumed that the quantity of 727-200 aircraft selected for the 1985 scenario would remain fixed in the 1990 scenario as the 727-200 will most likely be out of production by 1985.

The difference between the I and II alternative 1980 fleets in table 7-9 is the substitution of the DC-10-10D for the 727-300. We do not believe that both aircraft would exist simultaneously in a United fleet. In the 1980 alternative III we removed the fleet candidates which were almost identical to each other. The DC-10-10D was taken out to allow the L-1011 Short in the fleet and the existing DC-10-10 and 747-100 were taken out for the L-1011 Long and the DC-10-40D. For the 1985 fleet alternative, we tested all nine new near-term designs in an economic screen, but found only the 3000 mile, 200 and 400 passenger, \$79/m<sup>3</sup> (30¢/gal) of fuel design to be promising.

#### ECONOMICS OF AIRCRAFT MODIFICATIONS

Several proposals involved modifications for improved fuel consumption through improved aerodynamic performance and through new engines on current aircraft. Re-engining current aircraft using the assumptions given in this study is not a viable solution, as the cost of re-engining cannot be justified from operating improvement alone even over a fifteen year investment life.

Table 8-1 shows the results of the economic screen testing of the various modifications. The column headed "Without Modification" portrays at three representative distances the number of passengers required to meet the fifteen percent hurdle rate criteria in the original economic screen. Aerodynamic modifications appear to be marginally beneficial and we have assumed that all aircraft for which fuel benefit was estimated are so modified. As a result these improvements in economics were input to the FAN model. United has on earlier occasions, in conjunction with evaluation of noise issues, attempted to test the economic viability of re-engining certain aircraft to extend



their economic life. Our conclusions in these evaluations were that the cost of re-engining makes it uneconomic to retain older jet aircraft in the industry equipment inventory if re-engining, rather than noise suppression retrofit, becomes necessary.

### FLEET CAPITAL AND OPERATING FINDINGS

Findings from the FAN model fleet analysis for the three target years of 1980, 1985 and 1990 are as follows:

1980.-- Tables 8-2 and 8-3 show the fleet selection, capital requirement and operating data from our analysis. In the fleet selection, table 7-9, alternative I included the 727-300 and excluded the DC-10-10D, and alternative II included the DC-10-10D but excluded the 727-300. All other aircraft types were the same in both alternatives. We tested both of these fleet alternatives to see if a marked difference would be evident with preference shown between an aircraft with 156 seats versus an aircraft with 200 seats. Initially there was a demand for twice as many of both of these derivative aircraft as shown, but this solution used fewer 737 and 727-100 aircraft than logically would be in United's 1980 fleet. Subsequent iterations brought the level of 727-300/DC-10-10D aircraft in line with those shown in table 8-2. One of the major concerns in fleet planning is the development of phase-in schedules for new aircraft which tie with phase-out of aircraft being replaced. This assures avoiding peaks in aircraft introduction and phase-out schedules. We have used the same approach in this study to assure that the fuel saving candidates are being introduced in a quantity which would be in line with prudent fleet planning.

The fleet alternatives are shown in tables 8-2, 8-4 and 8-6. The "In Schedule" data in these tables denotes the FAN model solution to accommodate the forecast quantity of passengers in the market. However, this fleet solution is not a total schedule solution. To make sure that the schedule solution will route aircraft to reasonably meet operational requirements, we examined the FAN model schedule segment flow using United's general schedule criteria and added the aircraft units needed to meet this criteria. Those additional aircraft are in the columns labeled "Estimate for Operation and Timing". The schedule would most likely require additional aircraft if a stricter, marketing oriented, departure timing result was sought.

Alternative III flew a few more Standard DC-8 aircraft (at a 17% higher estimated fuel burn than in alternative II) and selected a substantial fleet of L-1011 Shorts as substitute for the DC-10 and the DC-10-10D which were not in this scenario.

In table 8-3 we have shown the capital requirements and operating data associated with the three 1980 alternatives. A quick comparison of the three alternatives would lead to the conclusion that alternative II is the best choice as:

- It requires only slightly more capital than alternative I but considerably less than alternative III.
- It produces the highest number of departures and the lowest load factor (RPM's divided by ASM's) required for the same rate of return level.
- It burns the least estimated amount of fuel.

The \$44.8 million estimated for aerodynamic modifications in table 8-3 is based on the manufacturer's modification cost estimates submitted as part of the study. It covers all aircraft in United's 1980 fleet for which an aerodynamic modification was deemed feasible. The high purchase prices for new aircraft found in alternative III are mostly due to the requirement of substituting a completely new fleet (L-1011 Short) for an already existing fleet (DC-10-10). The influx of larger aircraft in this fleet scenario is manifested in the number of daily departures which are considerably lower than United's 1973 actual 1540 daily departures. The Revenue Passenger Miles rejected reflect the total forecasted RPM's in the market which, due to prohibitive economics, could not be flown.

Estimated fuel consumption is based on United's experience (or on the estimate in the case of new aircraft) with fuel burn included for both flight and taxi. Such macro estimates are subject to some changes associated with new or different missions resulting from schedule changes over time and should only be used as an indication of the magnitude of fuel burned.

1985.-- Tables 8-4 and 8-5 show the 1985 results with respect to fleet, capital and operating data. In the 1985 fleet selection we have eliminated smaller size aircraft as they would be logical phase-out candidates due to load factor pressure. The standard size DC-8 has also been phased out because of its high operating cost. A mix of 727-200's, CL-1320's, DC-10-10D's and DC-10-10's replaces these aircraft. These aircraft serve the same markets as the aircraft they replace. The short-haul 737 is replaced with a combination of 727-200's and the relatively short-haul CL-1320. The 727-100 is replaced by (1) the CL-1320 over stage lengths up to the maximum range capability of the CL-1320, and (2) by DC-10-10D's over stage lengths that are beyond CL-1320's capability. An added number of DC-10-10's replace retired Standard DC-8's. Neither the 200 passenger, 3000 mile nor the 400 passenger, 3000 mile new near-term aircraft come into the final solution. Initially, a few new near-term aircraft were in the fleet selection but not enough to make their introduction in 1985 viable. Consequently, they were eliminated from the final fleet selection.

The capital requirement estimate in table 8-5 reflects the replacement assumptions in this study and, although this requirement is massive, we believe it is reasonable. However, at present profit levels, the airline industry cannot generate the capital required for its needs. The estimated value of retired aircraft shown in table 8-5 was calculated as follows:

737	-	\$2.7 Million	=	\$143 Million
727-100	-	.5 "	=	40 "
Std. DC-8	-	.1 "	=	3 "
				\$186 Million

Reflecting the increasing difficulty of meeting a fifteen percent investment hurdle rate with the forecast cost and yield assumptions, the FAN model opted in 1985 to carry the forecast market with 200 fewer departures using larger aircraft. This schedule raises the question of a downward spiral of fewer departures generating fewer passengers in a competitive environment. We have assumed that the total industry will be in this market situation and that no competitive disadvantage will occur from reductions in departures.

ASM's grew 24 percent over 1980 and RPM's grew 20 percent allowing the load factor pressure slight alleviation even though the number of departures per day dropped. This is brought about by a continual influx of larger aircraft. Fuel needed to produce one ASM fell 17% from the 1980 fleet mix. In total, fuel consumption was estimated to be 3% higher in 1985 than in 1980.

1990.-- Tables 8-6 and 8-7 show the results of 1990 market growth translated into the fleet mix and quantity shown. Both the 727-200 and DC-8-61/-62 aircraft are estimated to still be in service in 1990. Short-haul to intermediate-haul routes are flown by the CL-1320 and the 727-200 and long-haul markets are served by a combination of DC-8-61's, DC-10-10's and 747's. The DC-10-10D was selected by the model to operate at stage lengths beyond the range of the CL-1320. Judging from segment length and market size, as well as comparative economics between the two aircraft, the CL-1320 with an extended range would probably have been selected to fly all of the DC-10-10 markets.

Recent United experience with aircraft replacement proposals intended to cover aircraft which in the next five to ten years will be too small for most trunk carrier markets (737, 727-100 and DC-9-10/-30) has shown that the optimal size replacement for these under-120 seat aircraft is an aircraft between 160 and 180 seats. Aircraft with 200 or more seats were too large for the majority of these short- to medium-haul markets on a one for one replacement basis. The 727-300 is the right size, but as mentioned previously its operating economics defeated it as a replacement candidate. It is also becoming evident that forecasted fuel costs favor most two engine instead of three engine designs for medium and short haul markets. Since most of the new aircraft in this study have seating capacities of 200 passengers or more, we were not able to select large numbers of these aircraft because markets are not yet ready for that many seats per departure as replacement for under-120 seat aircraft.

Both the 200 passenger and 400 passenger, 3000 mile new near-term aircraft are used in very limited quantities. Outside this project, aircraft of this type would probably not have been introduced by 1990. Since their presence probably indicates a need for aircraft with these characteristics in greater quantity by 1995, we left them in the fleet mix.

The capital required (table 8-7) covers additions to the 1985 fleet to carry market growth between 1985 and 1990. No new aircraft types were introduced in the study for 1990 use. Using United's experience with the effects of inflation on new aircraft prices, we estimate that \$2.7 billion (in 1973 dollars) needed for capital requirements equals about \$8.25 billion in current (inflated) dollars.

Departures per day are shown to increase, reflecting a growing market. The increase in departures is also in larger, more fuel efficient aircraft, which improves fuel burn per ASM by a total of 22% since 1980. Total fuel burn is estimated to have grown by 11% from 1980 to accommodate a total market growth of nearly 40% over the ten year period from 1980 to 1990.

TABLE 8-1  
ECONOMICS OF AIRCRAFT MODIFICATIONS

No. of Psgrs Required for a 15% ROI at Representative Stage Lengths and Utilization									
Modification Level	Without Modifications			With Aero Mods			With Aero + Engine Mods		
Stage Length - n mi	86	434	868	86	434	868	86	434	868
737-200	295	71	N/A	295	71	N/A	N/A	N/A	N/A
727-100	351	76	70	350	75	69	N/A	N/A	N/A
727-200	385	87	81	384	86	81	N/A	N/A	N/A
DC-8-20	447	98	91	445	98	91	475	104	97
DC-8-51/-52	432	94	87	431	93	86	473	103	96
DC-8-61	512	110	101	510	109	100	547	118	109
DC-10-10	825	163	145	825	163	145	N/A	N/A	N/A
747-100	1118	215	189	1115	214	188	N/A	N/A	N/A

TABLE 8-2  
1980 FLEET SELECTION

Type	Number of Aircraft					
	Alternative I		Alternative II		Alternative III	
	In Schedule	Estimate for Operation + Timing	In Schedule	Estimate for Operation + Timing	In Schedule	Estimate for Operation + Timing
DC-10-40D	-	-	-	-	-	-
737-200	53	-	53	-	53	-
727-100	80	-	80	-	80	-
727-200	27	7	27	7	27	7
727-300	8	2	-	-	-	-
DC-8 STD	21	9	23	7	25	5
DC-8-61/-62	23	-	23	-	23	-
L-1011 SHORT	-	-	-	-	27	7
DC-10-100	-	-	6	2	-	-
DC-10-10	20	5	20	5	-	-
747-100	12	3	12	3	12	3
L-1011 LONG	-	-	-	-	0	0
	244	26	244	24	247	22
Load Factor	75%		75%		78%	

TABLE 8-3  
UNITED AIRLINES CAPITAL REQUIREMENT  
AND OPERATING DATA - 1980

	Alternative I	Alternative II	Alternative III
<u>Capital Requirements (1973 \$)</u>			
Aero Modifications	\$ 44.8 Million	\$ 44.8 Million	\$ 44.8 Million
New Aircraft Purchase (incl spares) 1976-1980	\$202.7 Million	\$217.6 Million	\$703.8 Million
<u>Operating Data/Day</u>			
Departures	1072	1092	1082
ASM's Flown	111.3 Million	111.4 Million	109.0 Million
RPM's Flown	83.1 Million	83.1 Million	83.1 Million
RPM's Rejected	0.3 Million	0.3 Million	0.3 Million
<u>Estimated Fuel Consumption</u>			
Kgs (Lbs)	9.036 Million (19.921 Million)	8.940 Million (19.709 Million)	9.148 Million (20.167 Million)
Kgs/ASM (Lbs/ASM)	0.0812 (0.1790)	0.0802 (0.1769)	0.0839 (0.1850)

TABLE 8-4  
1985 FLEET SELECTION

Type	Number of Aircraft			
	In Schedule 1980	Added 1981 - 1985		In Schedule 1985
		In Schedule	Estimate for Operation + Timing	
737-200	53	--	--	--
727-100	80	--	--	--
727-200	34	31	8	73
DC-8 STD	30	--	--	--
DC-8-61/-62	23	--	--	23
CL-1320	--	49	12	61
DC-10-10D	8	22	5	35
NNT 200-3000	--	--	--	--
DC-10-10	25 (37)	20	✓	50
747-100	15 (18)	3	--	18
NNT 400-3000	--	--	--	--
	268	125	30	260
Load Factor	75%	73%		

( ) = Aircraft currently on hand.

TABLE 8-5  
UNITED AIRLINES CAPITAL REQUIREMENT  
AND OPERATING DATA - 1985

<u>Capital Requirement (1973 \$)</u>	
New Aircraft Purchase (incl spares) 1981 - 1985	\$2,175 Million
Less estimated value of retired aircraft	186 "
Total	\$1,989 Million
<u>Operating Data/Day</u>	
Departures	872
ASM's Flown	138 Million
RPM's Flown	99.4 Million
RPM's Rejected	0.5 Million
<u>Estimated Fuel Consumption</u>	
Kgs (Lbs)	9.200 Million (20.283 Million)
Kgs/ASM (Lbs/ASM)	0.0667 (0.1470)

TABLE 8-6  
1990 FLEET SELECTION

Type	Number of Aircraft			
	In Schedule 1985	Added by 1990		In Schedule 1990
		In Schedule	Estimate for Operation + Timing	
727-200	73	--	--	73
DC-8-61/-62	23	--	--	23
CL-1320	61	4	1	66
DC-10-10D	35	--	--	35
NNT 200-3000	0	9	1	10
DC-10-10	50	--	--	50
747-100	18	--	--	18
NNT 400-3000	0	6	1	7
	260	19	3	282
Load Factor	73%	74%		

TABLE 8-7  
UNITED AIRLINES CAPITAL REQUIREMENT  
AND OPERATING DATA - 1990

<u>Capital Requirements (1973 \$)</u> New Aircraft Purchase (incl spares) 1986 - 1990	\$523 Million
<u>Operating Data/Day</u> Departures ASM's Flown RPM's Flown RPM's Rejected	972 159 Million 115.9 Million 0.7 Million
<u>Estimated Fuel Consumption</u> Kgs (Lbs) Kgs/ASM (Lbs/ASM)	9.966 Million (21.972 Million) 0.0627 (0.1382)

## SECTION 9

### TURBOPROP CONSUMER RESEARCH STUDY

Development of a new generation of turboprop transports to reduce energy consumption entails consideration of passenger attitudes towards such vehicles and resultant marketability of airline services utilizing them. Passenger expectations concerning internal noise, vibration, and ride quality have heightened with the wide scale use of jet aircraft even on relatively short trip segments. Jet speed automatically becomes a standard of comparison.

Passenger attitudes are probably strongly conditioned by prior experience in propeller driven airplanes and turboprops still currently in use. Some of these airplanes have engendered reputations with negative aspects. Safety hazards, real or implied, associated with exposed rotating propulsion systems are believed to be ever-present in the passenger's subconscious thought processes.

While fuel conservation and community noise improvement may not be direct passenger benefits, the passenger's perception of their general benefit to the public at large may temper his acceptance of turboprop transports, especially if maintenance of fare economy is also a consequence.

An inflight passenger survey, similar in form to those routinely conducted to assess other marketing subjects, was taken to explore passenger standards applicable to a new generation of turboprop transports. The survey questionnaire was designed to produce data sufficient to broadly evaluate basic passenger expectations and sensitivities that would be expected to apply to new "prop-fan" transports.

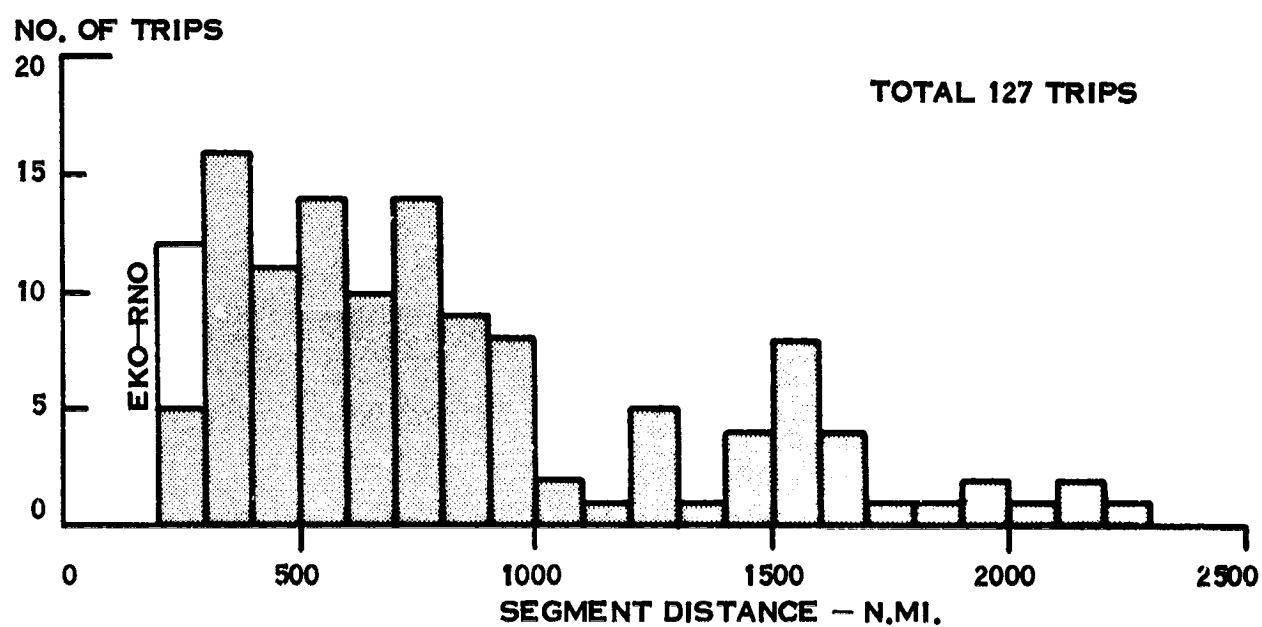
Some 13,500 questionnaires were circulated during a seven day period on 127 flights over 119 route segments ranging from 200 to 2300 nautical miles. Because of the special opportunity available, the survey included one trip daily operated with a Convair 580 on the 205 n mi segment from Elko to Reno.

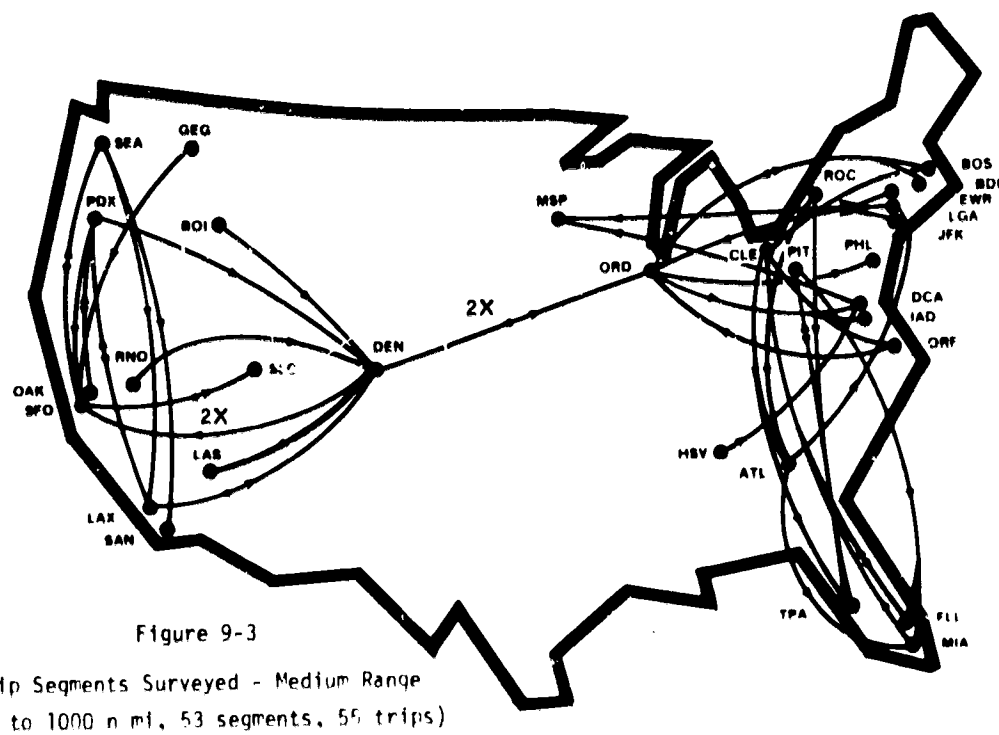
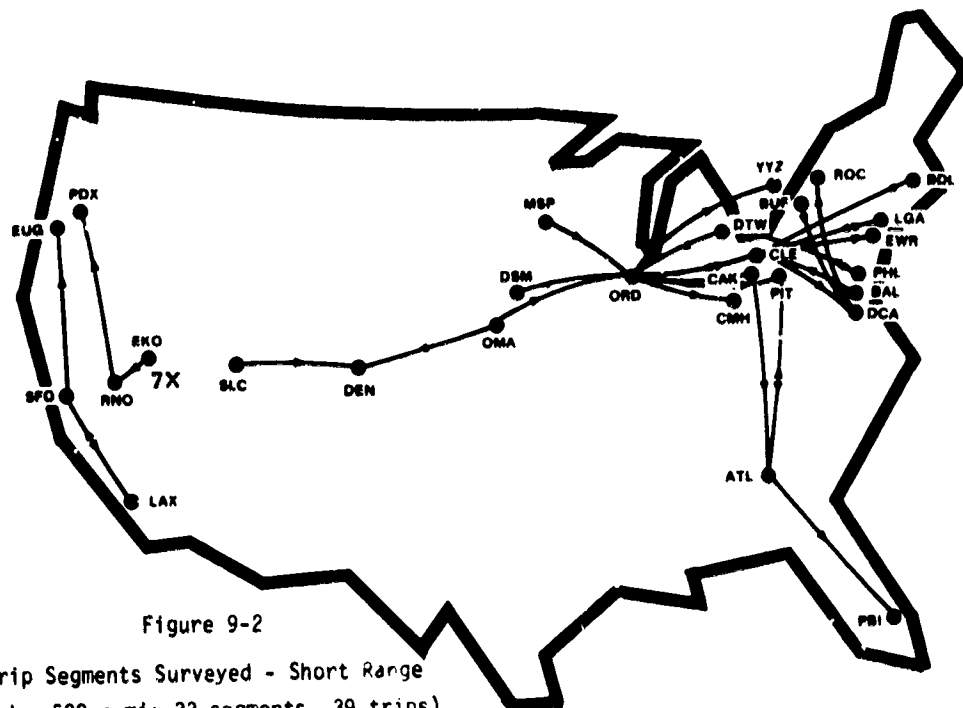
Figure 9-1 is a histogram showing the number of trips covered over various segment distances, figures 9-2 through 9-5 identify the specific segments that were surveyed and table 9-1 tabulates all the segments and their respective distances. Appendix C identifies the three letter airport codes.

A copy of the questionnaire is provided as appendix D. The first part of the questionnaire, through question 4c, was structured to identify the specific trip and aircraft type, to determine the passenger's trip purpose and his previous flying experience and to ascertain the pre-set standards he may have. The "prop-fan" was then introduced visually and the passenger's sensitivities and expectations tested (questions 5a through 6e). The closing questions produced information on flight bias and passenger demography.



Figure 9-1  
Turboprop Survey Trip Distribution





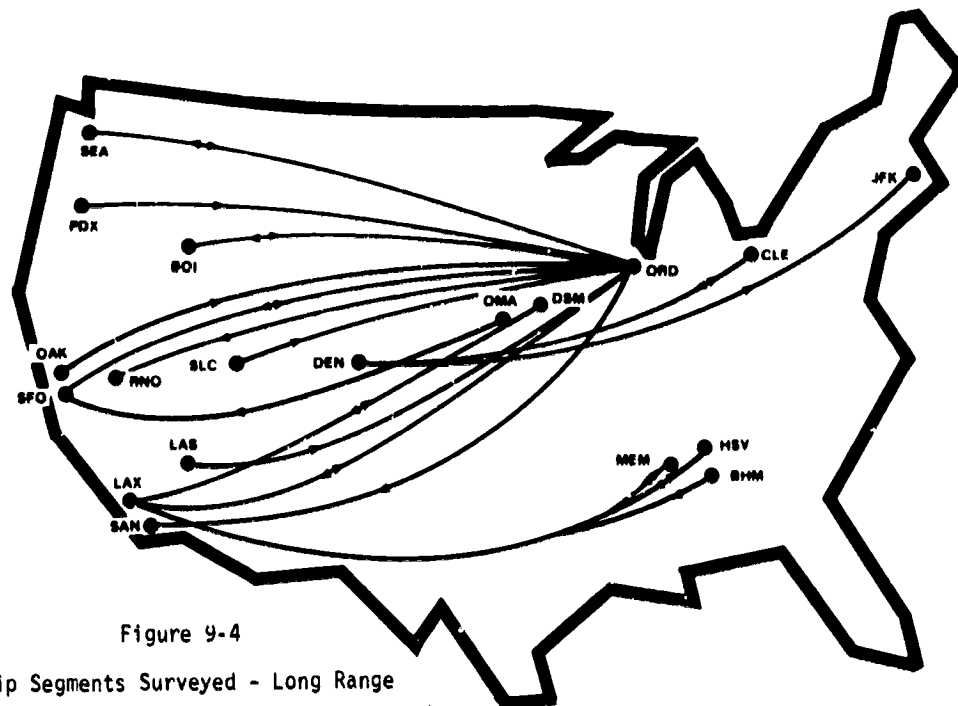


Figure 9-4  
 Trip Segments Surveyed - Long Range  
 (1000 to 1700 n mi; 25 segments, 25 trips)

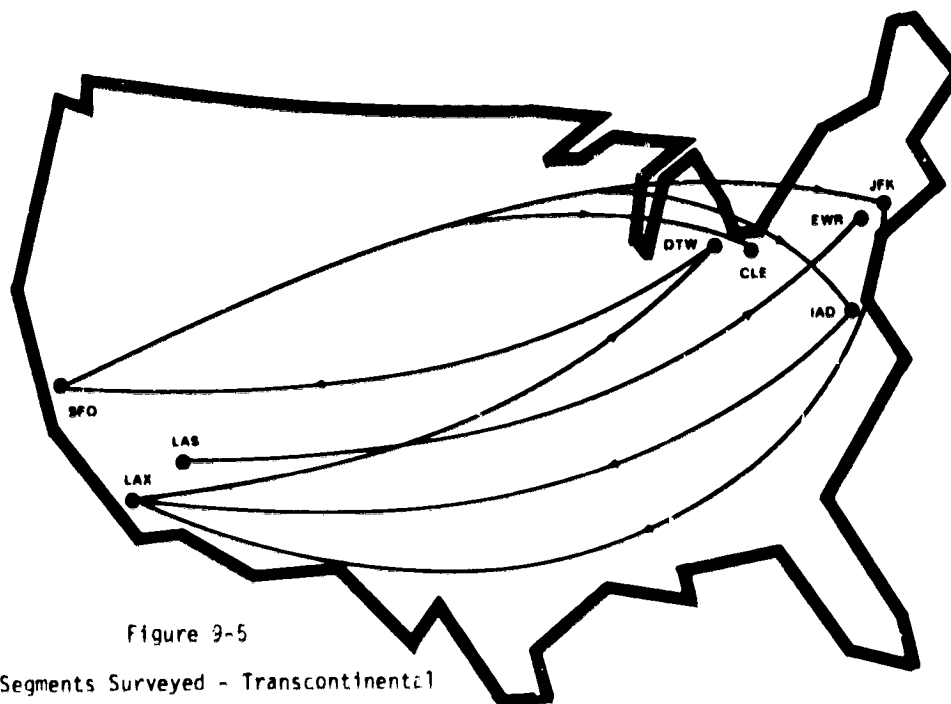


Figure 9-5  
 Trip Segments Surveyed - Transcontinental  
 (1700 to 2300 n mi, 8 segments, 8 trips)

TABLE 9-1  
TRIP SEGMENTS SURVEYED

Short Haul - Under 500 N M1								
EKO-RNO	205	n mi	CLE-ORD	305	DCA-DTW	382	RNO-PDX	424
DTW-ORD	220		LAX-SFO	311	PIT-ORD	383	OMA-DEN	430
BUF-DCA	270		MSP-ORD	311	LGA-CLE	384	PHL-DTW	432
ORD-CLE	274		BAL-CLE	312	CLE-EWR	386	BDL-CLE	440
DCA-ROC	283		ORD-CMH	318	OMA-ORD	388	ATL-PIT	474
DSM-ORD	288		CAK-ORD	345			ATL-PBI	487
			SLC-DEN	357	CLE-LGA	400	PIT-ATL	487
DCA-CMH	301		SFO-LAX	362	SFO-EUG	403	CAK-ATL	490
CLE-DCA	302		ORD-PIT	380	ORD-YYZ	404		

Medium Range - 500 to 1000 N Mi								
OAK-PDX	501	n mi	SFO-SEA	607	RNO-DEN	724	SEA-LAX	844
CLE-ATL	513		ORD-EWR	633	ORF-ORD	725	DCA-MSP	854
ORF-CLE	517		ORD-PHL	643	GEG-SFO	734	DEN-SFO	856
CLE-BOS	526		ORD-LGA	659	ORD-BOS	763	CLE-TPA	857
SFO-SLC	551		ORD-JFK	665	LAX-DEN	765	PDX-DEN	874
PDX-OAK	554		SEA-SFO	669	DEN-LAX	766		
ORD-IAD	555		EWR-ORD	671	LAX-PDX	766	PIT-MIA	908
PDX-SFO	557		ROC-ATL	684	PDX-LAX	766	PIT-FLL	921
HSV-DCA	558		LGA-ORD	686	ORD-DEN	781	LGA-MSP	924
ATL-MIA	559		ATL-LGA	698	BOS-ORD	792	SEA-SAN	943
DEN-LAS	561						FLL-CLE	957
SLC-SFO	568		BDL-ORD	705	DEN-ORD	800	ROC-TPA	960
BOI-DEN	572		ORD-BDL	713	PIT-TPA	802	CLE-FLL	972
ORD-DCA	579		JFK-ORD	719	TPA-PIT	804	MIA-CLE	974

Long Range - 1000 to 1700 N Mi								
DEN-CLE	1066	n mi	DSM-LAX	1281	SEA-ORD	1522	BHM-LAX	1589
CLE-DEN	1068		LAX-DSM	1281	ORD-SEA	1527	HSV-LAX	1595
SLC-ORD	1104		LAS-ORD	1357	PDX-ORD	1535	LAX-HSV	1610
BOI-ORD	1264		MEM-LAX	1430	ORD-LAX	1538	OAK-ORD	1622
ORD-BOI	1264		LAX-MEM	1445	ORD-SAN	1543	SFO-ORD	1644
OMA-SFO	1276		DEN-JFK	1459	LAX-ORD	1560	ORD-SFO	1661
			ORD-RNO	1469				

Transcontinental - 1700 to 2300 N Mi						
LAX-DTW	1749	n mi	SFO-CLE	1901	SFO-IAD	2136
DTW-SFO	1846		LAS-EWR	1948	JFK-LAX	2190
			IAD-LAX	2016	SFO-JFK	2284

## SURVEY RESULTS

### General Questions

A total of 4069 passengers responded to the survey. Table 9-2 summarizes the responses to some of the general questions asked of each respondent. Such questions included purpose of trip, age, sex, class of service and how many flights taken during the past twelve months. As to the number of flights, a "frequent" traveler is considered one who has flown ten or more times during the prior twelve month period.

Over 60% of the males were traveling for business purposes whereas over 70% of the females were traveling for pleasure purposes. Some attitudinal differences that exist between males and females are described later in this section. It is also observed that the first class/coach passenger split is 9%/91% which is nearly identical to the 10%/90% F/Y seat mix objective established for the overall study. Table 9-2 also includes the response distribution for survey questions 2a and 3a which pertain to prior travel on piston and turboprop aircraft, respectively. Three out of every four respondents had previously traveled in a piston-engined propeller driven airplane; and, 3 out of 5 had traveled in a turboprop vehicle. Surprisingly, perhaps, forty percent of the passengers who had never flown in a turboprop had prior experience in a piston-engined airplane.

As to why United was selected, question 1c, some cited quality of service but a larger number indicated that best departure time schedule was the reason for their selection.

### Pre-Set Attitudes

Jet-Propeller Attitudes.-- In response to question 3a, which was prior to introduction of the new prop-fan concept, there was an expected strong preference, 87%, for jets over propellers. Less than two percent of the respondents favored propellers in all response categories except one. There was an unexpected response from the Elko-Reno sample wherein 14% favored propellers. The reason for this difference is an apparent concern by travelers into and out of Elko (plus some other respondents) for airplanes that "can land at small airports".

The answers to questions 2b and 2d revealed attitudes more favorable toward turboprops than pistons. The comparison below forms the basis for this conclusion. The percentages total over 100% as a number of respondents cited more than one reason for their like or dislike. While the turboprop was treated more favorably than pistons it was generally disliked by 4 out of every 10 that had turboprop experience.

TABLE 9-2  
MISCELLANEOUS QUESTIONS RESPONSE DISTRIBUTION  
(% of Responses)

		Total	Trip Purpose		Travel Frequency		Sex		Class of Service		Traveled on Turboprop?	
			Bus.	Pleas.	Freq.	Infreq.	Male	Female	F.C.	Coach	Yes	No
Trip Purpose	Business Pleasure Combined	48%	--	--	81%	33%	62%	16%	62%	47%	63%	27%
		41	--	--	10	54	27	71	25	42	26	62
		11	--	--	9	13	11	13	13	11	11	11
Travel Frequency	Frequent Infrequent	35%	57%	9%	--	--	46%	10%	60%	33%	50%	12%
		65	43	91	--	--	54	90	40	67	50	88
Sex	Male Female	69%	90%	45%	92%	59%	--	--	78%	68%	85%	47%
		31	10	55	8	41	--	--	22	32	15	53
Class of Service	First Class Coach	9%	11%	5%	15%	6%	10%	6%	--	--	11%	5%
		91	87	95	85	94	90	94	--	--	89	95
Age	Under 30	28%	18%	38%	13%	36%	24%	36%	15%	29%	15%	48%
	30 - 49	46	58	32	60	40	51	34	50	46	56	31
	Over 49	26	24	30	27	24	25	30	35	25	29	21
Traveled on Piston A/C?	Yes	73%	86%	58%	92%	64%	84%	49%	85%	72%	94%	40%
	No/Don't Know	27	14	42	8	36	16	51	15	28	6	60
Traveled on Turboprop?	Yes	61%	79%	40%	88%	49%	74%	32%	79%	60%	--	--
	No/Don't Know	39	21	60	12	51	26	68	21	40	--	--

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<u>% Distribution of How Liked</u>		
	<u>Pistons (2b)</u>	<u>Turboprop (2d)</u>
<u>Unfavorable/Quasi-Unfavorable</u>		
Slower	9.5%	5. %
Noisy	12.5	8.5
Too much vibration	8.	4.5
Prefer jets	8.5	7.
Dislikes (unspecified)	18.	11.
Other miscellaneous dislikes	4.	2.5
Total	60.5%	38.5%
<u>Favorable/Quasi-Favorable</u>		
Better than piston	--	9. %
Good for short flights	3.5%	4.
Likes (unspecified)	36.5	49.
Other miscellaneous OK's	3.	3.
Total	43. %	65. %

Aspects of Flight.-- The passengers were asked to rank seven aspects of a flight from most important to least important. The ranking of aspect preference is shown below two ways: (1) based on arithmetic means and (2) based on first choice mentions.

	<u>Arithmetic Mean</u>		<u>First Choice</u>	
	<u>Mean Value</u>	<u>Rank</u>	<u>Distribution</u>	<u>Rank</u>
Seating Comfort	2.72	1	29%	1
Speed	3.30	2	28	2
Smoothness (lack of vibration)	3.48	3	14	4
Ride (lack of bumpiness)	3.74	4	15	3
Quietness	4.08	5	5	6
Flight Attendants	4.85	6	6	5
Food	5.27	7	3	7
			100%	

(Mean Value = Arithmetic mean of respondents' scoring the aspects on a scale of one to seven.)

Within specific categories there are some deviations from the composite picture. Some of these deviations are:

- The female passenger ranks ride and smoothness above speed.
- First class passengers give relatively more importance to flight attendants and food and less to ride and smoothness than does the composite traveler, however, the ranking does not change.
- The under-30 years of age group similarly gives more importance to flight attendants and food.

- The frequent traveler gives measurably more importance to seating comfort and to speed than does the composite traveler.

Question 4b asked what changes in flight features would be most liked and 4c asked which changes in airplane characteristics would be least acceptable. Some very strong attitudes emerged from these questions. Cheaper fares would be the most desirable change and closer seating the least desirable. Tabulated below are the response distributions to these questions. The totals exceed 100% due to multiple responses.

<u>Characteristics That Would Be Liked</u> <u>Most (4b)</u>	<u>Respondents</u>
Cheaper Fares	70%
Better Fuel Conservation	15
Higher Speed	12
Smoother Ride	8
More Service	6
Less Noise Around Airport	5
	<u>116%</u>
<u>Characteristics Least Acceptable (4c)</u>	
Slightly Closer Seating	58%
Slightly Bumpier Ride	17
Slightly More Vibration and Noise	16
Slightly Longer Flight Time	14
	<u>105%</u>

Analysis of specific response categories within question 4b shows consistency throughout. While the first class traveler and the frequent traveler place somewhat more emphasis upon more service and higher speed compared to other classifications, 6 out of 10 would still opt for lower fares.

Analysis of responses to question 4c reveals that:

- Although one-half the females would oppose closer seating it is not as important as it is to most other demographic classes. Females relatively are more concerned than others with ride quality.
- The frequent traveler was the strongest opponent of closer seating.
- The short-haul traveler showed slightly more concern for closer seating than did the medium- and long-haul passengers. This trend is presumed to be largely due to the closer seat pitch of short-haul aircraft. Those passengers on 3/4 full and full aircraft (question 8) did not show a significantly stronger opposition to closer seating than did those passengers aboard aircraft half full or less.



Prop-Fan Acceptance.-- After reading a description of the prop-fan and looking at a picture of it, respondents were asked (questions 5a and 5b) how they would feel about flying in the prop-fan plane for a trip such as the one they were on. Almost half of the total group (49%) had no pronounced positive or negative feelings and said they wouldn't care either way (other airline services being more important). However, 37% indicated they would want to fly on the prop-fan transport while 14% probably or definitely would not. The main reasons for respondents' propensity to try it were clustered around feelings of wanting to experience something (technology) that was new. On the other hand, respondents who were negative felt the plane would be slower, was a step backwards or gave them a general feeling of insecurity.

#### Attitudinal Shifts

After ascertaining an initial reaction to the advanced prop-fan concept, three questions (6a, 6b and 6c) were introduced which added a number of different variable characteristics. Question 6a introduced a 20% to 30% fuel savings over jet aircraft. Question 6b translated cost savings into avoidance of fare increases and question 6c asked passenger feelings toward the concept if less airport noise would be produced. These questions (and question 5a) all offered the same response alternatives to the situation described--definitely would want to, probably would want to, wouldn't care either way, probably would not want to, or definitely would not want to fly in a "prop-fan" plane.

Some pronounced shifts from the attitudes measured from question 5 responses were observed. For each question, the majority of respondents would probably or definitely want to try the prop-fan. Eighty-five (85) percent of the total group would most likely fly in a prop-fan transport if increases in fares would be avoided due to cost savings associated with this aircraft. The detail follows:

<u>Reaction</u>	<u>Total Respondents - %</u>			
	<u>(5a) Baseline</u>	<u>(6a) Fuel</u>	<u>(6b) Fare</u>	<u>(6c) Noise</u>
Definitely would	15	45	59	46
Probably would	22	31	26	26
Don't care	49	17	9	22
Probably not	11	5	4	4
Definitely not	3	2	2	2
	100	100	100	100

A specific breakdown of the shifts, i.e., the percentage shifts from one response alternative to another, is provided in table 9-3. The responses to the airport noise question, 6c, were perhaps biased by the previous fare question. The answers to question 4b indicated that the travelers perhaps did not consider airport noise a priority item. In retrospect, it might have been better to have placed the noise question prior to the fuel and fare questions.

TABLE 9-3  
PROP-FAN ATTITUDINAL SHIFTS

Basic Question: How would you feel about flying in the new "prop-fan" plane?

		Definitely Would	Probably Would	Wouldn't Care	Probably Not	Definitely Not
		Response Shift from Question 5a (baseline)				
To Question 6a (Fuel)	Definitely Would	--	49 %	38 %	6%*	8 %
	Probably Would	4 %	--	34 %	27%	12 %
	Wouldn't Care	4 %	5 %	--	20%	1½ %
	Probably Not	½ %	1 %	½ %	--	19½ %
	Definitely Not	1 %	nil	nil	2%	--
To Question 5b (Fare)	Definitely Would	--	67 %	58½ %	15%	8 %
	Probably Would	5 %	--	28 %	38%	15 %
	Wouldn't Care	3 %	3½ %	--	12%	6 %
	Probably Not	1 %	1 %	1 %	--	19 %
	Definitely Not	1 %	nil	nil	2%	--
To Question 6c (Airport Noise)	Definitely Would	--	54 %	41 %	9%	3 %
	Probably Would	5 %	--	29 %	23%	6 %
	Wouldn't Care	8 %	11 %	--	32%	17 %
	Probably Not	nil	½ %	½ %	--	17 %
	Definitely Not	1 %	-0-	nil	3%	--

6%  
27%  
20%  
--  
2%

Interpretive Example: Four hundred and three (403) travelers in answering question 5a said they probably would not want to fly in the new "prop-fan" airplane. When exposed to the 20% to 30% potential fuel saving of such an airplane (question 6a):

- 6% (23) of those 403 travelers changed their views and definitely would want to fly the vehicle.
- 27% (110 of the 403) shifted their response to probably would.
- 20% (81 of the 403) shifted to wouldn't care either way.
- 2% (8 of the 403) shifted to definitely not want to.
- The balance of the 403 maintained their previous probably not response or did not answer question 6a.

Longer Flight Time.-- Question 6e introduced a negative prop-fan variable regarding longer flying time: If the new "prop-fan" plane had flight times slightly longer (2 to 5 minutes per hour) than jets, how would this affect your flight selection for a trip such as the one you are on today?

The majority (56%) of respondents said this would not affect their choice of flights. Twenty-six (26) percent wouldn't care if the extra time was as much as five minutes per hour and 8% wouldn't care if the extra time was only two minutes per hour. On the other hand, 10% would go on a jet instead.

#### Passenger Expectations and Sensitivities to Particular Aircraft Types

After the above questions directly pertaining to the advanced prop-fan concept, three pictures of different aircraft types (labeled M, N and P) were presented: a four-engine, wing mounted turboprop (M); a two-engine, aft mounted turboprop (N); and a two-engine turbofan (P). The traveler was then asked to cite his preference (question 6e).

The majority (55%) of respondents preferred plane P, the jet. Twenty-eight (28) percent of those who chose plane P did so for reasons of speed ("faster"). (The respondents perceived the faster speed from the picture as there was no "jet" title nor any other direct notation of speed characteristics.) Interior noise consideration was the major reason for those that selected aft-engined plane N. The 11% who chose plane M did so mainly because they prefer more engines. The detailed findings are as follows:

<u>Aircraft Design Preference</u>	<u>Respondents</u>		
	<u>Total</u>	<u>Frequent Traveler</u>	<u>Infrequent Traveler</u>
Plane P	55%	64%	51%
Plane N	34	28	37
Plane M	11	8	12
Total	100%	100%	100%

<u>Reason for Preference</u>	<u>Plane Preferred by Total Respondents</u>		
	<u>Plane M</u>	<u>Plane N</u>	<u>Plane P</u>
Faster	4%	8%	28%
Less noise	3	27	9
Safer	20	3	7
Uses less fuel	12	13	1
Proven design	12	3	31
Like jets	1	2	21
Want to try something new	2	17	-
Like engine placement/location	5	18	-
Prefer more engines	24	2	-
Dependable/reliable	7	1	10
Other	32	37	20
Total*	122%	131%	127%

\* Totals exceed 100% due to multiple mentions.

#### SURVEY SUMMARY CONCLUSIONS

Seating comfort, fares and speed are the three most important of the many variables tested by this research. The advanced prop-fan concept, if able to hold down fare increases via lower operating costs, would be tried by eight out of ten respondents. However, even after introducing the energy saving, cost saving and airport noise reduction potential of the prop-fan, a majority of the respondents still exhibited jet plane preference (plane P) based on pictures of the possible aircraft. The following conclusions have been drawn from the analysis of the survey data:

- Though preferring a jet today, a passenger would fly an advanced prop-fan having jet equivalent speed, seating comfort and ride quality if he perceived a significant fuel savings attendant with the prop-fan.
- The passenger would fly an advanced prop-fan with a trip time measurably longer than jets if a direct financial advantage was associated with the prop-fan; e.g., a posted, discernible jet/prop-fan fare differential.

## SECTION 10

### RESEARCH AND TECHNOLOGY RECOMMENDATIONS

United Airlines recommends continued development by the NASA of all those technologies applicable to "next generation" turbofan transports having fuel efficiency benefits. Investigation of these benefits was beyond the scope of this study but they are evident from projected development of such technologies as:

- o Supercritical aerodynamics
- o Composite structures
- o Active flight controls
- o Propulsive efficiency improvement

Also, two of the fuel conserving options evaluated during this study potentially offer a favorable benefit/cost ratio. These two options require further technical evaluation and are recommended below for continued research and technology study by the National Aeronautics and Space Administration.

#### Winglets/Wing Tip Extension and General Drag Reduction

Advanced research is recommended to definitize the costs and the fuel reduction benefits of the winglets and/or wing tip extensions and the general drag improvements. The four to seven and one-half percent fuel savings adopted in this study warrants thorough evaluation of the retrofit opportunity as well as the manufacturers' break-in change opportunities.

The cost evaluation should include not only detailed analysis of airplane investment and retrofit out-of-service costs, but also the cost impact at the airport due to any wing span increase.

#### Advanced Turboprop Aircraft

The substantially lower fuel consumption and attendant lower DOC's that the advanced turboprop airplane potentially offers dictates that we recommend NASA's continued evaluation of the "prop-fan" concept. Research should continue taking into consideration these consumer attitudes toward introduction of a new generation of turboprops:

Ride quality and comfort must equal or exceed that of current turbofan powered aircraft.

- Vehicle speed is an important aspect of flight. Consumers would accept somewhat longer trip times than current turbofans if lower operating costs produce lower fares or stem future fare increases.

From an airline standpoint, a "slower" turboprop would not be purchased for operations over segments in direct competition (at the same fare) with a turbofan. Therefore, the NASA's research should focus upon turbofan equivalent speeds or, if significantly slower cruise speed is essential to prop-fan fuel efficiency, upon governmental changes to the air transport system that would encourage introduction of a "slow" airplane. In this context, "equivalent speed" does not necessarily mean specifically equal design cruise Mach number. There is some latitude available in operating speeds, resulting in relatively small differences in trip times which would not be perceived by the traveler as indicative of a "slower" airplane. We suspect that responses to the speed question in the turboprop passenger survey may be biased by having introduced the subject of fare benefits in a preceding question. However, the split in responses between the 5 minute, 2 minute, and "go-jet" choices suggests, perhaps, an inability to perceive 2 minutes per flight hour as significant. Two minutes per hour is equivalent to about .03 in cruise Mach number.

## SECTION 11

### CONCLUSIONS

The salient conclusions of this study are:

- Within the existing ATC system, there are no significant fuel conserving opportunities available via revised flight procedures. Reduced cruise speed procedures, most frequently cited as such an opportunity, were implemented by United prior to the 1973 fuel crisis.
- Putting more people in the airplanes, by increasing seating density and/or increasing load factors, can significantly increase fuel efficiency. Such action might, however, increase total fuel consumed. This could happen if the density increases produce lower costs thence lower fares resulting in an increased travel demand that requires additional trips.
- Re-engining retrofit modification of narrow body four engine aircraft, while a fuel saving opportunity, would not be economically viable.
- Fuel saving aerodynamic modifications (drag reduction and winglets or wing tip extensions) offer a marginal, but positive, economic payoff.
- New turbofan aircraft designs (new near-term aircraft) whose aerodynamic configurations are a function of post-Arab oil embargo fuel prices would likely be viable, fuel conserving products.
- Derivative designs of existing aircraft (727, DC-10, L-1011, etc.) also would be viable products, earlier perhaps than the new designs due to lower airline investment requirements. These aircraft, whose basic aerodynamics are pre-oil embargo, achieve improved fuel efficiency through capacity increases or technology improvements such as the incorporation of supercritical airfoils, composite materials and other drag and weight reductions.
- Air travelers today are very sensitive to fare levels, seating comfort and speed. An advanced turboprop that is responsive to these aspects would be acceptable to the consumer. Some speed penalty would be tolerable for the passenger if that penalty directly translates into fare savings.

APPENDIX A

FUEL CONSERVING AIRCRAFT  
FUEL CONSUMPTION AND EFFICIENCY

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BLOCK FUEL CONSUMPTION -  
RETROFIT MODIFICATIONS

Trip Distance - Naut. Miles	BLOCK FUEL - $\frac{\text{kg}}{\text{ap1-mile}}$ $\left(\frac{\text{gal}}{\text{ap1-mile}}\right)$				
	737-200	727-100	727-200	DC-10-10	747-100
200	9.99 (3.23)	--	--	--	--
300	8.72 (2.82)	12.12 (3.92)	13.41 (4.35)	--	--
500	7.71 (2.50)	9.99 (3.24)	10.85 (3.52)	17.51 (5.68)	30.19 (9.79)
750	7.52 (2.44)	9.13 (2.96)	9.87 (3.20)	--	--
1000	7.40 (2.40)	8.69 (2.82)	9.37 (3.04)	14.58 (4.73)	22.94 (7.44)
1500	--	--	--	14.15 (4.59)	--
1750	--	8.39 (2.72)	9.16 (2.97)	--	--
2000	--	--	--	14.28 (4.63)	21.40 (6.94)
2500	--	--	--	14.49 (4.70)	--
3000	--	--	--	--	21.83 (7.08)
4000	--	--	--	--	22.54 (7.31)

BLOCK FUEL CONSUMPTION -  
RETROFIT MODIFICATIONS (Continued)

	Trip Distance - Naut. Miles	BLOCK FUEL - $\frac{\text{kg}}{\text{apl-mile}}$ $\left(\frac{\text{gal}}{\text{apl-mile}}\right)$			
		DC-8-20	DC-8-51/-52	DC-8-61	DC-8-62
Aerodynamic Modifications Only	500	17.88 (5.80)	14.86 (4.82)	17.64 (5.72)	17.58 (5.70)
	1000	15.05 (4.88)	12.52 (4.06)	14.34 (4.65)	12.80 (4.15)
	1500	14.37 (4.66)	11.90 (3.86)	13.41 (4.35)	--
	2000	14.15 (4.59)	11.72 (3.80)	13.13 (4.26)	11.65 (3.78)
	2500	14.15 (4.59)	11.75 (3.81)	13.04 (4.23)	--
	3000	--	--	--	11.84 (3.84)
	4500	--	--	--	12.39 (4.02)
Aerodynamic and Engine Modifications	500	13.54 (4.39)	13.29 (4.31)	15.79 (5.12)	15.79 (5.12)
	1000	11.41 (3.70)	11.19 (3.63)	12.83 (4.16)	11.47 (3.72)
	1500	10.88 (3.53)	10.64 (3.45)	11.99 (3.89)	--
	2000	10.73 (3.48)	10.48 (3.40)	11.75 (3.81)	10.48 (3.40)
	2500	10.73 (3.48)	10.51 (3.41)	11.65 (3.78)	--
	3000	--	--	--	10.64 (3.45)
	4500	--	--	--	11.13 (3.61)

BLOCK FUEL CONSUMPTION -  
DERIVATIVE AIRPLANES

Trip Distance - Nautical Miles	BLOCK FUEL - $\frac{\text{kg}}{\text{apl-mile}}$ $\left(\frac{\text{gal}}{\text{apl-mile}}\right)$				
	727-300	L-1011 Short	L-1011 Long	DC-10-10D	DC-10-40D
100	--	27.36 (9.03)	30.29 (9.82)	40.30 (13.06)	51.33 (16.64)
300	15.27 (4.95)	--	--	--	--
500	12.40 (4.02)	--	--	13.96 (4.52)	20.76 (6.73)
600	--	16.81 (5.45)	19.90 (6.45)	--	--
750	10.98 (3.56)	--	--	--	--
1000	10.30 (3.33)	14.92 (4.83)	18.19 (5.89)	11.29 (3.66)	16.96 (5.49)
1750	9.77 (3.17)	--	--	--	--
2000	--	13.87 (4.49)	17.63 (5.71)	10.66 (3.45)	15.59 (5.05)
2600	--	13.83 (4.48)	--	--	--
3000	--	--	17.82 (5.78)	10.77 (3.49)	15.75 (5.10)

BLOCK FUEL CONSUMPTION -  
NEW NEAR-TERM AND ADVANCED PROP-FAN AIRCRAFT

Trip Distance - Naut. Miles	BLOCK FUEL - $\frac{\text{Kg}}{\text{apl-mile}}$ ( $\frac{\text{gal}}{\text{apl-mile}}$ )					
	New Near-Term			Advanced Prop-Fan CL-1320-13		
	200-1500-30	200-1500-60	200-1500-Min			
100	26.52 (8.60)	26.52 (8.60)	22.51 (7.30)	20.35 (6.60)		
500	11.53 (3.74)	11.10 (3.60)	10.92 (3.54)	8.93 (2.89)		
750	10.12 (3.28)	9.84 (3.19)	9.59 (3.11)	7.90 (2.56)		
1000	9.68 (3.14)	9.28 (3.01)	8.97 (2.91)	7.33 (2.37)		
1500	9.31 (3.02)	8.88 (2.88)	8.54 (2.77)	6.97 (2.25)		
	New Near-Term			New Near-Term		
	200-3000-30	200-3000-60	200-3000-Min	400-3000-30	400-3000-60	400-3000-Min
100	30.84 (10.00)	30.84 (10.00)	27.14 (8.80)	44.38 (14.39)	40.46 (13.12)	40.71 (13.20)
500	12.92 (4.19)	12.61 (4.09)	12.21 (3.96)	20.69 (6.71)	19.68 (6.38)	20.14 (6.53)
1000	10.42 (3.38)	9.99 (3.24)	9.99 (3.24)	17.64 (5.72)	16.65 (5.40)	16.78 (5.44)
2000	9.65 (3.13)	9.19 (2.98)	9.16 (2.97)	16.65 (5.40)	15.88 (5.15)	15.88 (5.15)
3000	9.90 (3.21)	9.31 (3.02)	9.13 (2.96)	16.96 (5.50)	16.07 (5.21)	15.85 (5.14)

FUEL EFFICIENCY -  
RETROFIT MODIFICATIONS

Trip Distance - Naut. Miles	DC-10-10				747-100			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
500	13.3	(41.1)	3247	(3077)	10.5	(32.2)	4140	(3924)
1000	16.0	(49.4)	2704	(2562)	13.7	(42.4)	3146	(2982)
1500	16.5	(50.9)	2624	(2487)	--	--	--	--
2000	16.3	(50.4)	2646	(2508)	14.7	(45.5)	2935	(2781)
2500	16.1	(49.7)	2686	(2546)	--	--	--	--
3000	--	--	--	--	14.5	(44.6)	2994	(2837)
4000	--	--	--	--	14.0	(43.2)	3091	(2930)
	727-100				727-200			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
300	8.0	(24.6)	5424	(5141)	9.1	(28.2)	4729	(4483)
500	9.7	(29.8)	4472	(4238)	11.3	(34.9)	3827	(3627)
750	10.6	(32.7)	4085	(3872)	12.4	(38.4)	3479	(3298)
1000	11.1	(34.3)	3892	(3689)	13.1	(40.4)	3305	(3133)
1750	10.5	(32.6)	4099	(3885)	13.4	(41.3)	3229	(3060)
	737-200							
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)				
200	9.3	(28.6)	4669	(4425)				
300	10.6	(32.7)	4078	(3866)				
500	12.0	(37.0)	3604	(3415)				
750	12.3	(38.0)	3516	(3333)				
1000	12.5	(38.6)	3459	(3278)				

FUEL EFFICIENCY -  
RETROFIT MODIFICATIONS (Continued)

Trip Distance - Naut. Miles	DC-8-20 Aerodynamic Modifications Only				DC-8-20 Aerodynamic and Engine Modifications			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
500	6.7	(20.8)	6420	(6085)	8.9	(27.5)	4860	(4606)
1000	3.0	(24.7)	5402	(5120)	10.6	(32.6)	4096	(3882)
1500	8.4	(25.9)	5158	(4889)	11.1	(34.2)	3908	(3704)
2000	8.5	(26.3)	5081	(4816)	11.2	(34.6)	3852	(3651)
2500	8.5	(26.3)	5081	(4816)	11.2	(34.6)	3852	(3651)
	DC-8-51/-52 Aerodynamic Modifications Only				DC-8-51/-52 Aerodynamic and Engine Modifications			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
500	8.2	(25.4)	3252	(4978)	9.2	(28.4)	4697	(4451)
1000	9.8	(30.2)	4424	(4193)	10.9	(33.7)	3956	(3749)
1500	10.3	(31.7)	4206	(3987)	11.5	(35.5)	3760	(3563)
2000	10.4	(32.2)	4141	(3925)	11.7	(36.0)	3705	(3512)
2500	10.4	(32.1)	4152	(3935)	11.6	(35.9)	3716	(3522)
	DC-8-61 Aerodynamic Modifications Only				DC-8-61 Aerodynamic and Engine Modifications			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
500	9.4	(28.9)	4616	(4375)	10.5	(32.3)	4132	(3916)
1000	11.5	(35.6)	3752	(3557)	12.9	(39.8)	3357	(3182)
1500	12.3	(38.0)	3510	(3327)	13.8	(42.5)	3139	(2975)
2000	12.6	(38.8)	3438	(3258)	14.1	(43.4)	3075	(2914)
2500	12.7	(39.1)	3414	(3235)	14.2	(43.7)	3050	(2891)
	DC-8-62 Aerodynamic Modifications Only				DC-8-62 Aerodynamic and Engine Modifications			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
500	7.3	(22.4)	5957	(5646)	8.1	(24.9)	5351	(5071)
1000	10.0	(30.8)	4337	(4111)	11.1	(34.3)	3888	(3685)
2000	11.0	(33.8)	3950	(3744)	12.2	(37.6)	3553	(3368)
3000	10.8	(33.2)	4013	(3804)	12.0	(37.0)	3606	(3417)
4500	10.3	(32.8)	4201	(3982)	11.5	(35.4)	3773	(3576)

FUEL EFFICIENCY -  
DERIVATIVE AIRPLANES

Trip Distance - Naut. Miles	DC-10-10D				DC-10-40D			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
100	4.9	(15.2)	8762	(8305)	6.4	(19.6)	6792	(6437)
500	14.2	(44.0)	3036	(2877)	15.7	(48.6)	2747	(2603)
1000	17.6	(54.4)	2455	(2327)	19.3	(59.4)	2244	(2127)
2000	18.7	(57.6)	2318	(2197)	21.0	(64.7)	2063	(1956)
3000	18.5	(57.0)	2343	(2221)	20.7	(64.0)	2085	(1976)
	L-1011 Short Body				L-1011 Long Body			
100	7.2	(22.1)	6029	(5714)	13.4	(41.4)	3220	(3052)
600	11.9	(36.7)	3638	(3448)	20.4	(63.1)	2116	(2005)
1000	13.4	(41.3)	3229	(3060)	22.4	(69.0)	1934	(1833)
2000	14.4	(44.4)	3002	(2846)	23.1	(71.2)	1875	(1777)
2600	14.5	(44.6)	2992	(2836)	--	--	--	--
3000	--	--	--	--	22.8	(70.4)	1895	(1796)
	727-300							
300	10.2	(31.5)	4237	(4016)				
500	12.6	(38.8)	3441	(3262)				
750	14.2	(43.8)	3046	(2887)				
1000	15.1	(46.7)	2857	(2707)				
1750	16.0	(49.2)	2712	(2571)				

FUEL EFFICIENCY -  
NEW NEAR-TERM AND ADVANCED PROP-FAN

Trip Distance - Naut. Miles	New Near-Term 200·1500·30				New Near-Term 200·1500·60			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
100	7.5	(23.2)	5738	(5439)	7.5	(23.2)	5738	(5439)
500	17.3	(53.4)	2501	(2370)	18.0	(55.5)	2403	(2277)
750	19.8	(61.0)	2189	(2075)	20.3	(62.7)	2130	(2018)
1000	20.6	(63.6)	2097	(1987)	21.5	(66.3)	2013	(1908)
1500	21.4	(66.1)	2020	(1914)	22.5	(69.3)	1925	(1825)
	New Near-Term 200·1500·Min				Advanced Prop-Fan CL-1320-13			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
100	8.9	(27.4)	4871	(4617)	9.8	(30.3)	4404	(4174)
500	18.3	(56.5)	2363	(2240)	22.4	(69.0)	1933	(1832)
750	20.8	(64.2)	2080	(1971)	25.3	(78.1)	1709	(1620)
1000	22.3	(68.7)	1942	(1841)	27.3	(84.1)	1587	(1504)
1500	23.3	(72.0)	1853	(1756)	28.7	(88.5)	1508	(1429)
	New Near-Term 200·3000·30				New Near-Term 200·3000·60			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
100	6.5	(20.0)	6673	(6325)	6.5	(20.0)	6673	(6325)
500	15.5	(47.7)	2796	(2650)	15.8	(48.8)	2734	(2591)
1000	19.1	(59.0)	2260	(2142)	19.9	(61.6)	2168	(2054)
2000	20.7	(63.8)	2092	(1983)	21.7	(67.0)	1990	(1887)
3000	20.2	(62.3)	2143	(2031)	21.4	(66.0)	2021	(1916)
	New Near-Term 200·3000·Min				New Near-Term 400·3000·30			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
100	7.4	(22.7)	5873	(5566)	9.0	(27.8)	4804	(4553)
500	16.4	(50.5)	2644	(2506)	19.3	(59.6)	2239	(2122)
1000	19.9	(61.6)	2168	(2055)	22.6	(69.8)	1911	(1811)
2000	21.8	(67.1)	1986	(1885)	24.0	(74.0)	1803	(1709)
3000	21.9	(67.4)	1980	(1876)	23.6	(72.7)	1837	(1741)
	New Near-Term 400·3000·60				New Near-Term 400·3000·Min			
	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)	ASM's kg	(ASM's) (gal)	Kilo- joules ASM	(BTU's) (ASM)
100	9.9	(30.5)	4378	(4150)	9.8	(30.3)	4404	(4174)
500	20.3	(62.7)	2130	(2018)	19.8	(61.2)	2181	(2067)
1000	24.0	(74.1)	1802	(1708)	23.8	(73.5)	1815	(1721)
2000	25.1	(77.5)	1721	(1632)	25.1	(77.6)	1720	(1630)
3000	24.9	(76.7)	1740	(1649)	25.2	(77.8)	1715	(1625)



APPENDIX B

1980 MARKET FORECAST  
BY SEGMENT

PRECEDING PAGE BLANK NOT FILMED

# 1980 MARKET FORECAST BY SEGMENT

Average Number of Passengers per Day in One Direction -  
Same Number Assumed for Opposite Direction

<u>Segment</u>	<u>Psgrs/Day</u>	<u>Segment</u>	<u>Psgrs/Day</u>	<u>Segment</u>	<u>Psgrs/Day</u>
ABE-CLE	82.9	BHM-CHA	33.1	CLE-CRW	74.4
-ORD	173.1	-CLT	48.1	-DCA	615.4
ABE-PIT	65.3	BHM-LAX	105.8	-DEN	212.4
ATL-AVL	63.9	BOI-DEN	191.0	-DSM	140.1
-BUF	150.5	-GEG	57.9	-EWR	447.9
-CAK	156.0	-LAX	63.8	-FLL	159.5
-CLE	406.0	-ORD	90.3	-FNT	125.2
-CRW	146.3	-PDT	41.9	-FWA	180.2
-FLL	137.4	-PDX	163.7	-GRR	218.3
-JAX	76.2	-SEA	70.6	-JFK	211.8
-LGA	77.2	-SFO	159.9	-LAN	115.6
-MIA	118.6	BOI-SLC	140.6	-LAS	150.4
-ORF	253.6	BOS-CLE	457.6	-LAX	214.6
-PBI	133.5	-DEN	188.2	-LGA	677.4
-PHF	128.9	-MSP	89.3	-MBS	159.5
-PIT	222.2	-ORD	492.5	-MIA	188.7
-ROC	131.0	BOS-SFO	149.9	-MKE	174.7
-TPA	147.5	BUF-DCA	117.8	-MLI	71.0
ATL-YNG	82.9	-DEN	92.2	-MSP	91.3
AVL-RDU	50.8	-FLL	28.4	-MSY	66.1
BAL-BUF	13.6	-MIA	69.3	-OMA	149.2
-CLE	194.8	-ORD	155.4	-ORD	512.8
-DEN	98.9	-PHL	123.1	-ORF	136.4
-DTW	101.6	-PIT	44.2	-PBI	34.5
-LAX	77.1	-ROC	57.3	-PDX	91.3
-MCI	69.9	BUF-TPA	83.2	-PHL	459.8
-ORD	361.8	CAK-DEN	75.2	-PIT	71.5
-PHF	44.2	-LGA	75.2	-PVD	55.4
-RJC	24.9	-ORD	233.2	-SAN	141.4
BAL-SFO	70.6	-PIT	22.7	-SBN	179.0
BDL-CLE	293.4	CAK-YNG	33.0	-SEA	133.9
-LAX	81.0	CHA-TYS	74.2	-SFO	218.0
BDL-ORD	389.5	CID-CLE	66.7	-SLC	66.7
BFL-LAX	176.5	-DEN	138.3	-TOL	212.6
-MOD	73.5	CID-ORD	278.9	CLE-TPA	208.2
-SFO	76.2			CLT-MEM	39.5
BFL-VIS	60.1			CMH-DAY	24.6
				-DCA	143.0
				CMH-ORD	221.0

<u>Segment</u>	<u>Psgs/Day</u>	<u>Segment</u>	<u>Psgs/Day</u>	<u>Segment</u>	<u>Psgs/Day</u>
CRW-LGA	66.7	DSM-LAX	85.1	IAD-LAX	218.5
-PIT	80.0	-OMA	14.1	-MCI	75.9
CRW-TRI	30.1	DSM-ORD	461.0	-ORD	75.2
				-RIC	111.9
DAY-DCA	81.0	DTW-LAS	83.8	IAD-SFO	264.5
-DEN	100.9	-LAX	140.2		
DAY-ORD	181.0	-ORD	402.6	JAX-PIT	25.7
		-PHL	242.3		
DCA-DTW	134.2	DTW-SFO	145.8	JFK-LAS	99.3
-HSV	73.5			-LAX	299.0
-MSP	64.9	EUG-PDX	76.1	-OMA	65.0
-ORD	555.3	EUG-SFO	172.1	-ORD	351.0
-ORF	111.0			-SEA	207.0
-PHF	57.4	EWR-GSO	207.2	-SFO	295.3
-PIT	151.6	-LAS	73.9	JFK-SLC	101.3
-RIC	76.3	-LAX	191.0		
-ROC	137.5	-ORD	635.4	LAN-ORD	188.2
DCA-TYS	164.8	-RDU	53.2		
		-SFO	174.9	LAS-LAX	110.2
DEN-DSM	348.1	-TOL	72.8	-MKE	75.2
-DTW	241.8	EWR-YNG	67.7	LAS-ORD	702.5
-EWR	250.3				
-FAT	146.5	FAT-LAX	400.1	LAX-MEM	117.1
-GEG	168.9	FAT-SFO	428.7	-MKE	134.2
-GJT	56.4			-MRY	279.5
-GRR	87.9	FLL-PIT	134.4	-OMA	200.3
-IAD	315.0	FLL-ROC	30.1	-ORD	641.7
-JFK	301.1			-PDX	308.1
-LAS	397.4	FNT-ORD	162.9	-PHL	121.5
-LAX	547.0			-PIT	81.0
-LNK	56.4	FWA-ORD	239.3	-RNO	75.2
-MCI	123.9	FWA-SBN	33.0	-SAN	365.9
-MCE	330.0			-SBA	201.5
-MLI	139.2	GEG-LAX	33.0	-SEA	531.8
-OAK	73.5	-PDX	37.5	-SFO	309.8
-OMA	358.1	GEG-SFO	176.0	LAX-VIS	54.5
-ONT	69.6				
-ORD	476.6	GJT-LAS	65.1	LGA-MSP	160.9
-PDX	231.5			-ORD	395.2
-PHL	187.4	GRR-MBS	29.9	LGA-TYS	122.8
-PIT	126.9	GRR-ORD	233.1		
-RNO	175.5			LNK-OMA	12.4
-SBN	81.0	GSO-HSV	103.0	LNK-ORD	186.2
-SEA	359.6	GSO-RDU	107.5		
-SFO	629.0			MBS-ORD	276.1
-SJC	132.6	HSV-LAX	150.5		
-SLC	295.2	HSV-TYS	41.3	MCE-SCK	52.8
DEN-SMF	251.1			MCE-VIS	47.1

<u>Segment</u>	<u>Psgs/Day</u>
MCI-PHL	68.3
-SEA	76.2
MCI-SFO	87.4
MEM-TYS	38.5
MFR-PDX	27.3
-SFO	200.0
MFR-SLE	42.0
MIA-PIT	195.2
MIA-ROC	51.9
MKE-SFO	66.7
MKG-ORD	110.1
MLI-ORD	297.5
MOD-SCK	30.1
MOD-SFO	91.0
MRY-SFO	277.2
MSP-ORD	490.8
MSY-PIT	131.0
OAK-ORD	107.8
-PDX	193.8
OAK-SEA	81.0
OMA-ORD	458.0
ONT-ORD	148.7
ORD-ORF	227.1
-PDX	345.9
-PHF	103.5
-PHL	696.4
-PIT	336.3
-PVD	148.5
-RNO	160.8
-ROC	121.7
-SAN	342.9
-SBN	234.2
-SEA	596.4
-SFO	538.3

<u>Segment</u>	<u>Psgs/Day</u>
ORD-SJC	168.3
-SLC	310.6
-SMF	148.6
-TOL	333.5
-YNG	138.3
-YVR	81.0
ORD-YYZ	211.2
PBI-PIT	34.0
PDT-PDX	92.4
PDX-RNO	209.9
-SEA	320.3
-SFO	391.4
-SLE	21.7
PDX-SMF	143.9
PHL-ROC	98.0
PHL-SFO	93.9
PIT-TPA	208.5
-TYS	33.7
PIT-YNG	74.2
RNO-SEA	145.0
-SFO	232.4
RNO-SMF	19.7
ROC-TPA	86.8
SAN-SEA	130.7
SBA-SFO	232.5
SCK-SFO	157.2
SEA-SFO	614.0
-SLC	61.2
SEA-YVR	259.0
SFO-SLC	265.4
-SMF	127.4
SFO-VIS	59.7
SLC-SMF	85.9

APPENDIX C

CITY AND AIRPORT CODES

# CITY AND AIRPORT CODES

ABE - Allentown-Bethlehem-Easton, Pa.  
 ATL - Atlanta, Ga.  
 AVL - Asheville, N.C.

BAL - Baltimore, Md.  
 BDL - Hartford, Conn.  
 BFL - Bakersfield, Calif.  
 BHM - Birmingham, Ala.  
 BOI - Boise, Idaho  
 BOS - Boston, Mass.  
 BUF - Buffalo, N.Y.

CAK - Akron-Canton, Ohio  
 CHA - Chattanooga, Tenn.  
 CID - Cedar Rapids, Iowa  
 CLE - Cleveland, Ohio  
 CLT - Charlotte, N.C.  
 CMH - Columbus, Ohio  
 CRW - Charleston, W. Va.

DAY - Dayton, Ohio  
 DCA - Washington, D.C.  
 DEN - Denver, Colo.  
 DSM - Des Moines, Iowa  
 DTW - Detroit, Mich.

EUG - Eugene, Ore.  
 EWR - Newark, N.J.

FAT - Fresno, Calif.  
 FLL - Fort Lauderdale, Fla.  
 FNT - Flint, Mich.  
 FWA - Fort Wayne, Ind.

GEG - Spokane, Wash.  
 GJT - Grand Junction, Colo.  
 GRR - Grand Rapids, Mich.  
 GSO - Greensboro, N.C.

HSV - Huntsville, Ala.

IAD - Dulles Airport, D.C. - Va.

JAX - Jacksonville, Fla.  
 JFK - J. F. Kennedy Airport, N.Y.

LAN - Lansing, Mich.  
 LAS - Las Vegas, Nev.  
 LAX - Los Angeles, Calif.  
 LGA - LaGuardia Airport, N.Y.  
 LNK - Lincoln, Neb.

MBS - Saginaw, Mich.  
 MCE - Merced, Calif.  
 MCI - Kansas City, Mo.  
 MDW - Midway Airport, Chicago, Ill.  
 MEM - Memphis, Tenn.  
 MFR - Medford, Ore.  
 MIA - Miami, Fla.  
 MKE - Milwaukee, Wis.  
 MKG - Muskegon, Mich.  
 MLI - Moline, Ill.  
 MOD - Modesto, Calif.  
 MRY - Monterey, Calif.  
 MSP - Minneapolis, Minn.  
 MSY - New Orleans, La.

OAK - Oakland, Calif.  
 OMA - Omaha, Neb.  
 ONT - Ontario, Calif.  
 ORD - O'Hare Airport, Chicago, Ill.  
 ORF - Norfolk, Va.

PBI - West Palm Beach, Fla.  
 PDT - Pendleton, Ore.  
 PDX - Portland, Ore.  
 PHF - Newport News, Va.  
 PHL - Philadelphia, Pa.  
 PIT - Pittsburgh, Pa.  
 PVD - Providence, R.I.

RDU - Raleigh-Durham, N.C.  
 RIC - Richmond, Va.  
 RNO - Reno, Nev.  
 ROC - Rochester, N.Y.

CITY AND AIRPORT CODES (Continued)

SAN - San Diego, Calif.  
SBN - South Bend, Ind.  
SCK - Stockton, Calif.  
SEA - Seattle-Tacoma, Wash.  
SFO - San Francisco, Calif.  
SJC - San Jose, Calif.  
SLC - Salt Lake City, Utah  
SLE - Salem, Ore.  
SMF - Sacramento, Calif.

VIS - Visalia, Calif.

YNG - Youngstown, Ohio  
YVR - Vancouver, B.C., Canada  
YYZ - Toronto, Ont., Canada

TOL - Toledo, Ohio  
TPA - Tampa, Fla.  
TRI - Bristol-Kingsport-Johnson City, Tenn.  
TYS - Knoxville, Tenn.

APPENDIX D

PASSENGER SURVEY



# Passenger Survey

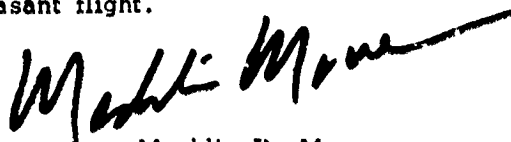
Dear Passenger:

Thank you for flying United today. We hope this trip in the "Friendly Skies of Your Land" lives up to your expectations.

United Airlines is participating in a joint industry-government study concerning the application of new technology to future aircraft. We would appreciate your taking a few minutes to complete this questionnaire. The information you provide will help in the development of these aircraft. A flight attendant will collect the completed forms shortly.

If you have comments in addition to those you included in the questionnaire, we are always pleased to hear from you.

Have a pleasant flight.



Mechlin D. Moore  
Group Vice President -  
Marketing  
United Airlines  
P.O. Box 66100  
Chicago, Ill. 60666



FROM \_\_\_\_\_ TO \_\_\_\_\_  
FLIGHT # \_\_\_\_\_ DATE \_\_\_\_\_

1a. What is or was the MAIN purpose of this trip?

- 1 ☐ Business  
2 ☐ Pleasure, Personal  
3 ☐ Both

1b. During the past 12 months, considering all flights to all destinations, how many total air round trips have you made prior to this trip?

\_\_\_\_\_ Total number of trips

1c. Specifically, why was this flight on United selected for your trip?

\_\_\_\_\_  
\_\_\_\_\_

1d. What type of fare plan are you using for this flight?

- 1 ☐ Full Fare      2 ☐ Discount Fare

2a. Have you ever traveled in piston-engined propeller driven airplanes? (For example, DC-3, DC-6 Series, DC-7 Series, Constellation, Martin 202/404, Convair 240/340.)

- 1 ☐ Yes (Please answer Qu. 2b)  
2 ☐ No  
3 ☐ Don't know      } Skip to Qu. 2c

2b. How did you like that type of aircraft? \_\_\_\_\_

\_\_\_\_\_

2c. Have you ever traveled in turbine-engined propeller driven ("turbo-prop") airplanes? (For example, Lockheed Electra, Convair 580/640, Fairchild F-27 or F-227, Bristol Britannia, Vickers Viscount, YS-11.)

- 1 ☐ Yes (please answer Qu. 2d)  
2 ☐ No  
3 ☐ Don't know      } Skip to Qu. 2e

2d. How did you like that type of aircraft? \_\_\_\_\_

\_\_\_\_\_

2e. What type of plane are you flying in today?

- 1 ☐ B-737      5 ☐ B-747  
2 ☐ B-727      6 ☐ Other \_\_\_\_\_  
3 ☐ DC-8      (please specify)  
4 ☐ DC-10      7 ☐ Don't know

3a. For a flight like the one you are on today, which type of aircraft do you prefer?

1 ☐ Prop Plane      2 ☐ Jet Plane      3 ☐ No Preference

3b. Why?

---

---

4a. Please rank each of the following aspects of a flight in order of importance to you with 1 being most important and 7 being least important.

_____ Food	_____ Smoothness (lack of vibration)
_____ Seating comfort	_____ Ride (lack of bumpiness)
_____ Quietness	_____ Flight Attendant service
_____ Speed	

4b. Which one of the following changes in features of a flight would you like the most?

1 <input type="checkbox"/> Better fuel conservation	5 <input type="checkbox"/> More service
2 <input type="checkbox"/> Higher speed	6 <input type="checkbox"/> Less noise around airports
3 <input type="checkbox"/> Cheaper fares	
4 <input type="checkbox"/> Smoother ride	

4c. Which one of the following changes in airplane characteristics would you be least likely to accept?

1 ☐ Slightly more vibration and noise  
2 ☐ Slightly bumpier ride  
3 ☐ Slightly longer flight time  
4 ☐ Slightly closer seating

A future type of airplane using advanced design propellers is now being studied. These new "prop-fan" planes could fly as high, as safely, and almost as fast and smooth as jet aircraft. They would be turbine driven, just like current jets, and there would be nearly the same lack of internal noise and vibration. Compared to today's turboprops, the new "prop-fans" would be improved. The "prop-fans" themselves might look more like fan blades than propellers, as shown in the following picture:



5a. How would you feel about flying in the new "prop-fan" plane for a trip such as the one you are on today?

- 1 ☐ I definitely would want to.
- 2 ☐ I probably would want to.
- 3 ☐ I wouldn't care either way.
- 4 ☐ I probably would not want to.
- 5 ☐ I definitely would not want to.

5b. Why? \_\_\_\_\_

6a. Suppose that the new "prop-fan" aircraft used 20% to 30% less fuel than a jet aircraft. Then how would you feel about flying in the new "prop-fan" plane for a trip such as the one you are on today?

- 1 ☐ I definitely would want to.
- 2 ☐ I probably would want to.
- 3 ☐ I wouldn't care either way.
- 4 ☐ I probably would not want to.
- 5 ☐ I definitely would not want to.

6b. If air fare increases in the future were avoided because of the savings associated with this new aircraft, how would you feel about flying in the new "prop-fan" plane for a trip such as the one you are on today?

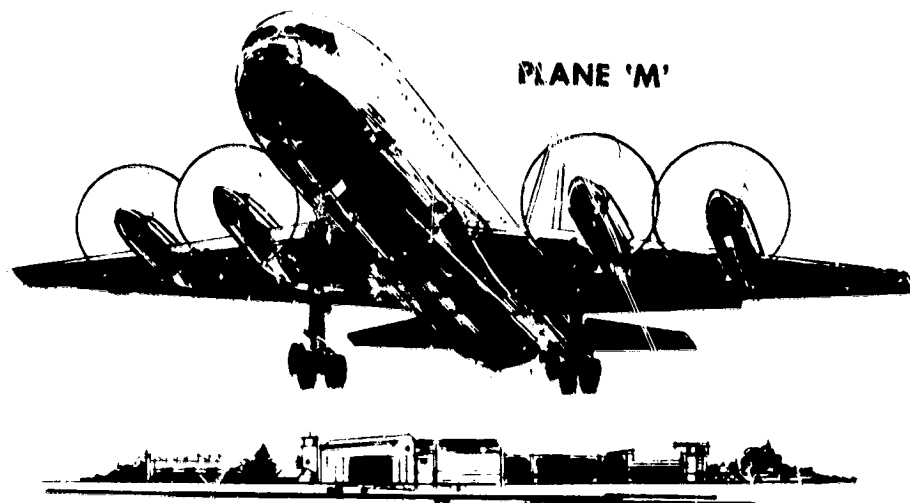
- 1 ☐ I definitely would want to.
- 2 ☐ I probably would want to.
- 3 ☐ I wouldn't care either way.
- 4 ☐ I probably would not want to.
- 5 ☐ I definitely would not want to.

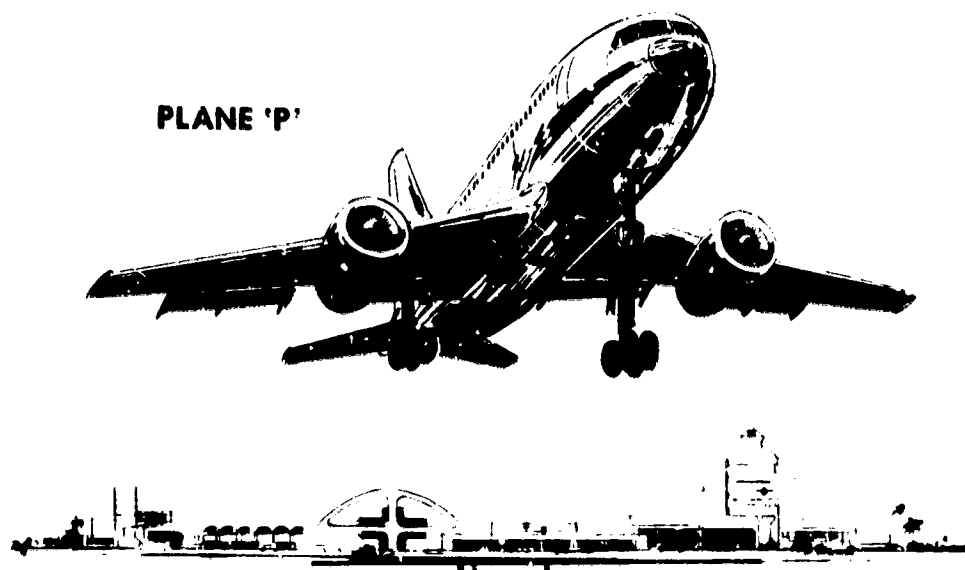
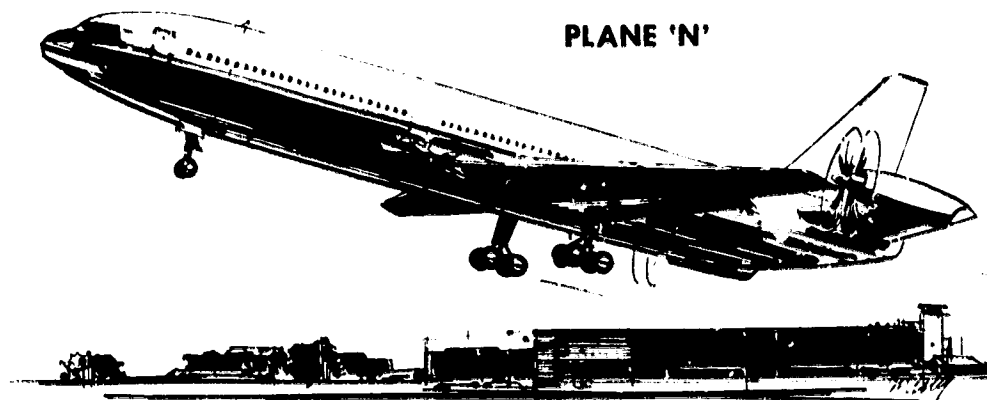
6c. Suppose that the new "prop-fan" aircraft made less noise around airports than a new jet aircraft. Then how would you feel about flying in the new "prop-fan" plane for a trip such as the one you are on today?

- 1 ☐ I definitely would want to.
- 2 ☐ I probably would want to.
- 3 ☐ I wouldn't care either way.
- 4 ☐ I probably would not want to.
- 5 ☐ I definitely would not want to.

6d. If the new "prop-fan" plane had flight times slightly longer (2 to 5 minutes per hour) than jets, how would this affect your flight selection for a trip such as the one you are on today?

- 1 ☐ It would not affect my choice of flights.
- 2 ☐ I wouldn't care if the extra time was as much as 5 minutes per hour.
- 3 ☐ I wouldn't care if the extra time was only 2 minutes per hour.
- 4 ☐ I'd go jet.





6e. Which plane would you prefer to travel in for a trip such as today's?

1 ☐ Plane M

2 ☐ Plane N

3 ☐ Plane P

Why? \_\_\_\_\_

7a. On today's trip, did this plane take off on time or was it delayed?

1 ☐ On time (please skip to Qu. 8)

2 ☐ Delayed (please answer Qu. 7b)

7b. How many minutes was it delayed?

\_\_\_\_\_ # of minutes

8. Would you say your section of the plane was....

1 ☐ Full

3 ☐ About Half full

2 ☐ Three-Quarters full

4 ☐ Less than Half full

9. Please indicate how much you agree or disagree with the following statement: This flight was quite smooth - that is, not bumpy.

1 ☐ Strongly disagree

4 ☐ Somewhat agree

2 ☐ Disagree

5 ☐ Agree

3 ☐ Somewhat disagree

6 ☐ Strongly agree

NOW, JUST A FEW QUESTIONS FOR CLASSIFICATION PURPOSES  
ONLY -- ANSWERS ARE STRICTLY CONFIDENTIAL.

10a. What class of air service are you using on this flight?

1 ☐ First Class (F)

2 ☐ Coach/Tourist (Y)

10b. Are you an airline employee, relative, or travel agent?

1 ☐ Yes

2 ☐ No

10c. Are you....

1 ☐ Male

2 ☐ Female

10d. Are you....

1 ☐ Married

2 ☐ Single

10e. What is your age?

\_\_\_\_\_ Years

10f. What is your occupation?

- 1 ☐ Executive, manager
- 2 ☐ Professional, technical
- 3 ☐ Teacher, professor
- 4 ☐ Salesman, buyer
- 5 ☐ Government, military
- 6 ☐ Secretary, clerk, office worker

7 ☐ Craftsman, mechanic, factory worker

8 ☐ Homemaker

9 ☐ Student

0 ☐ Religious, clergy

X ☐ Retired

☐ Other

(please fill in)

10g. What is your approximate family income? (Of your total household.)

- 1 ☐ Under \$7,000
- 2 ☐ \$7,000 - \$9,999
- 3 ☐ \$10,000 - \$14,999
- 4 ☐ \$15,000 - \$19,999
- 5 ☐ \$20,000 - \$24,999
- 6 ☐ \$25,000 - \$34,999
- 7 ☐ \$35,000 - \$49,999
- 8 ☐ \$50,000 - \$64,999
- 9 ☐ \$65,000 and over

10h. What is your home state and Zip Code?

THANK YOU VERY MUCH.



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